

Mammal decline in southern Western Australia – perspectives from Shortridge's collections of mammals in 1904-07

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ABSTRACT

Guy Shortridge made extensive collections of mammals in southern Western Australia in the years 1904 to 1907, less than 80 years after first European settlement of the area. This paper reviews Shortridge's unpublished letters and the published papers that resulted from his collections in a re-examination of the temporal and spatial patterns of decline of these mammals. Shortridge collected a monotreme, 25 species of marsupial, 10 species of bat, 8 species of rodent, as well as rabbits and dingoes (a total of 46 species). He collected in five broad regions: mesic woodland sites in what is now the western wheatbelt; mesic coastal scrub sites around Albany; mesic forest habitat in the far south-west corner at Margaret River, Busselton, and Bunbury; semi-arid pastoral sites at Carnarvon and Gascoyne Junction; and semi-arid mining sites at Southern Cross, Kalgoorlie and Laverton. Shortridge was struck particularly by the rich fauna of the mesic woodland and the lack of species in the semi-arid interior (he obtained 20 terrestrial native species at the former and only 3-5 species at the latter). However, since that time, several of the species Shortridge collected at the mesic woodland sites have become extinct on mainland Australia (*Bettongia lesueur*, *Lagostrophus fasciatus*, and *Perameles bougainville*) or are now extinct (*Onchogalea lunata*) and the region shows one of the highest losses of mammals within Australia. Shortridge's collections emphasise that the loss of mammals in Western Australia has been a two-step process, with an initial loss of mammals in the semi-arid interior, followed by a subsequent loss from mesic woodland and coastal sites. His collections preceded the arrival of foxes *Vulpes vulpes* to the State and largely preceded the spread of rabbits *Oryctolagus cuniculus*. Shortridge speculated that disease, predation by feral cats *Felis catus*, competition from house mice *Mus musculus*, and bushfires were major factors in overall decline, and the impact of closer settlement was important in localised declines. These, and other factors commonly cited as reasons for mammal decline (grazing and land clearing), are evaluated. The factors suggested by Shortridge for overall decline are potentially interlinked: feral cats or house mice may spread disease, feral cats may be more effective as predators in the presence of abundant house mice populations and at sites where vegetation refuges are reduced by fire, and both may reach highest densities around farms and settlements. The pattern of loss to 1907 can be explained by the spread of feral cats only if their impact on native mammals is high in semi-arid pastoral and mining areas, low in mesic areas, and low in arid areas where European impact was minimal. Possible mechanisms for such a variable impact of feral cats include: i) greater density of vegetation at mesic sites providing refuge for prey species; ii) protection conferred to prey species by poison plants *Gastrolobium* in the understorey of mesic woodland leading to secondary poisoning of predators; and iii) Aboriginal hunting of feral cats being effective in limiting the density and impact of cats in remote areas beyond the frontier of European colonisation.

Key words: extinction, fox, feral cat, disease, *Gastrolobium*, historical ecology

Introduction

Burbidge and McKenzie (1989) noted that the extent of extinction of mammals in Australia since European settlement has no recent parallel on any other continent. Southern Western Australia has experienced one of the greatest levels of regional extinction of mammals anywhere in Australia (Woinarski and Braithwaite 1990), the losses being greatest in wheatbelt, pastoral and desert areas. The loss of mammals has been variously attributed to the displacement of Aboriginal people and the change in the pattern of burning (Kitchener *et al.* 1980), disease (White 1952; How *et al.* 1987; Richards and Short 1996), predation by foxes *Vulpes vulpes* (Kinnear *et al.* 1988; Friend 1990),

a reduction in environmental productivity occasioned by grazing, land clearing, and introduction of exotic species (Burbidge and McKenzie 1989), and clearing and habitat fragmentation within wheatbelt areas (Hobbs *et al.* 1993). The level of extinctions and declines has been greatest among marsupials and native rodents and least among bats and monotremes (Short and Smith 1994).

Guy Chester Shortridge made extensive collections of mammals and birds in southern Western Australia for the British Museum of Natural History in the early 1900s. Shortridge collected at a time when the sheep population of the state was small (about 3.34 million in 1906, which was

8.7% of the maximum in 1990: Government Statistician's Office 1908 and Western Australian Yearbooks) and prior to major land clearance for cropping (about 176,000 ha were cropped for grain and hay in 1906, which was 2.6% of the maximum area attained in 1985). His collection also preceded the arrival of rabbits *Oryctolagus cuniculus* to most collecting localities and preceded the arrival of foxes *Vulpes vulpes* by some 20 years. This study examines the collections and notes of Shortridge with a view to re-examining the pattern of decline he observed in the context of new knowledge and contemporary views on the loss of mammals.

Methods

Shortridge's collections, notes and correspondence

Shortridge's letters pertaining to his expedition to Australia were sourced from the Battye Library in Perth and the British Museum of Natural History in London (Appendix 1). These were read in conjunction with Shortridge's publications (1909 and 1936), those of Ogilvie-Grant (1909 and 1910), and Thomas (1906a, b) to establish Shortridge's itinerary of travel, collection methods and precise localities of collections where possible, and to extract key information pertaining to fauna and environment. Direct quotes are referenced to a particular letter by use of a subscript corresponding to its number in Appendix 1. Extraneous material (material not directly relevant to his collection methods or

descriptions of mammals or locality) is omitted for brevity. Square brackets indicate text added by me for clarity. A question mark against a species name reflects Shortridge's uncertainty over identification.

Shortridge's collections of non-volant critical weight range mammal species (species within the weight range of 35 g to 4.2 kg, a range that includes virtually all Western Australian species suffering extinction or decline: Burbidge and McKenzie 1989) for five broad locations in Western Australia were compared with species lists derived from the known former distributions of species in these areas (by reference to Strahan 1995). This allowed an assessment of the degree to which the faunas of each district were intact at that time. The attributes of each location in 1906 were derived from historical sources. These included land use, population density, areas of privately owned and leasehold land, sheep and cattle numbers, and the area subject to cropping. Appendix 2 gives the common and scientific names for mammals used by Shortridge and the corresponding names from Strahan (1995).

Results

The collector

Guy Chester Shortridge (1880-1949) was an Englishman from Devon who had previous experience of collecting mammals and birds in Africa. He had served in the South African Constabulary during the Boer War of 1899-1901 and was engaged by the then Director of the South African Museum to collect mammals and birds in Pondoland

Table 1. A chronology of travel by Shortridge in Western Australia November 1904 - June 1907, reconstructed from letters and dates given in Ogilvie-Grant (1910).

Location	Dates
Arrived Fremantle (5 days) and thence to Albany	November 1904
Albany (Albany Harbour; King George's Sound, Oyster Harbour, Pelican Point, Rabbit Island, Brambles Beach, King River, Big Grove, Little Grove, Kalgan, Kalgan River, and Chorkerup)	January – May 1905
Arthur River, 20 miles west of Wagin	June 1905
Beverley	July 1905
Southern Cross (Crookerdine Lake, 5 miles north; Parker's Range, 30 miles south)	July – August, 1905
Kalgoorlie (Kurrawang, 60 miles from Kalgoorlie; Jaurdi Hills)	September – October 1905
Laverton (North Pool, 10 miles from Laverton; Hawks Nest)	October - November 1905
Beverley (County Peak, 30 miles east; Dale River 16 miles west; Boyadine Camp, 18 miles west)	December 1905 – January 1906
Beverley (White Wells, 45 miles east; Stock Pool, 30 miles east (9 days))	January 1906
Dwaladine (20 miles east of Brookton), Mt Kokeby	February 1906
Woyaline (20 miles east of Pingelly)	April 1906
Beverley (letter)	May 1906
Carnarvon (arrival – Geraldton and Denham on route; back to Denham for dugongs)	June 1906
Bernier Island	June –July 1906
Carnarvon and Gascoyne River	July –September 1906
Clifton Downs (180 miles east towards Peak Hill) and Upper Gascoyne River	September –October 1906
Busseton (Beachlands)	January –February 1907
Margaret River (Rapids, Burnside and Ellenbrook)	February –April 1907
Wonnerup-Busseton (Yallingup)	May 1907
Departed Perth for Java	June 1907

(Whittell 1954). He was engaged in Britain by Oldfield Thomas, Curator of Mammals at the British Museum of Natural History, on behalf of the benefactor W.E. Balston. Shortridge maintained regular communication with both Thomas and Balston.

Shortridge travelled from England to Fremantle by the ship "Omrah" arriving in late November 1904. He spent 5 days in Perth visiting the Premier, the Perth Zoo, and the Western Australian Museum. He collected a free rail pass (with the help of a letter of introduction from the Office of the Agent General for Western Australia in London) and this became his major method of moving about the State. He travelled to Albany by rail and stayed at "one of Mr Balston's farms about seven miles out of town" (his letter

was addressed c/- Mr E. Balston, King River, Albany⁴). Balston had two sons managing farms at Albany – the other farm was apparently near Tambellup, "between 80-90 miles up country"³. He then travelled by rail back towards Perth stopping at several locations, before taking a train to the Eastern Goldfields. Subsequently, he took a coastal steamer from Perth to Carnarvon some 900 km to the north. A chronology of his travels is presented in Table 1 and they are mapped in Figure 1 from maps accompanying one of his letters.

Shortridge had guns and ammunition and purchased a horse and trap (a two-wheeled carriage). He employed some 200 breakback or foot-hold traps (described as "wooden spring" or "gin" traps)¹⁷ of a range of sizes suitable for mouse-sized

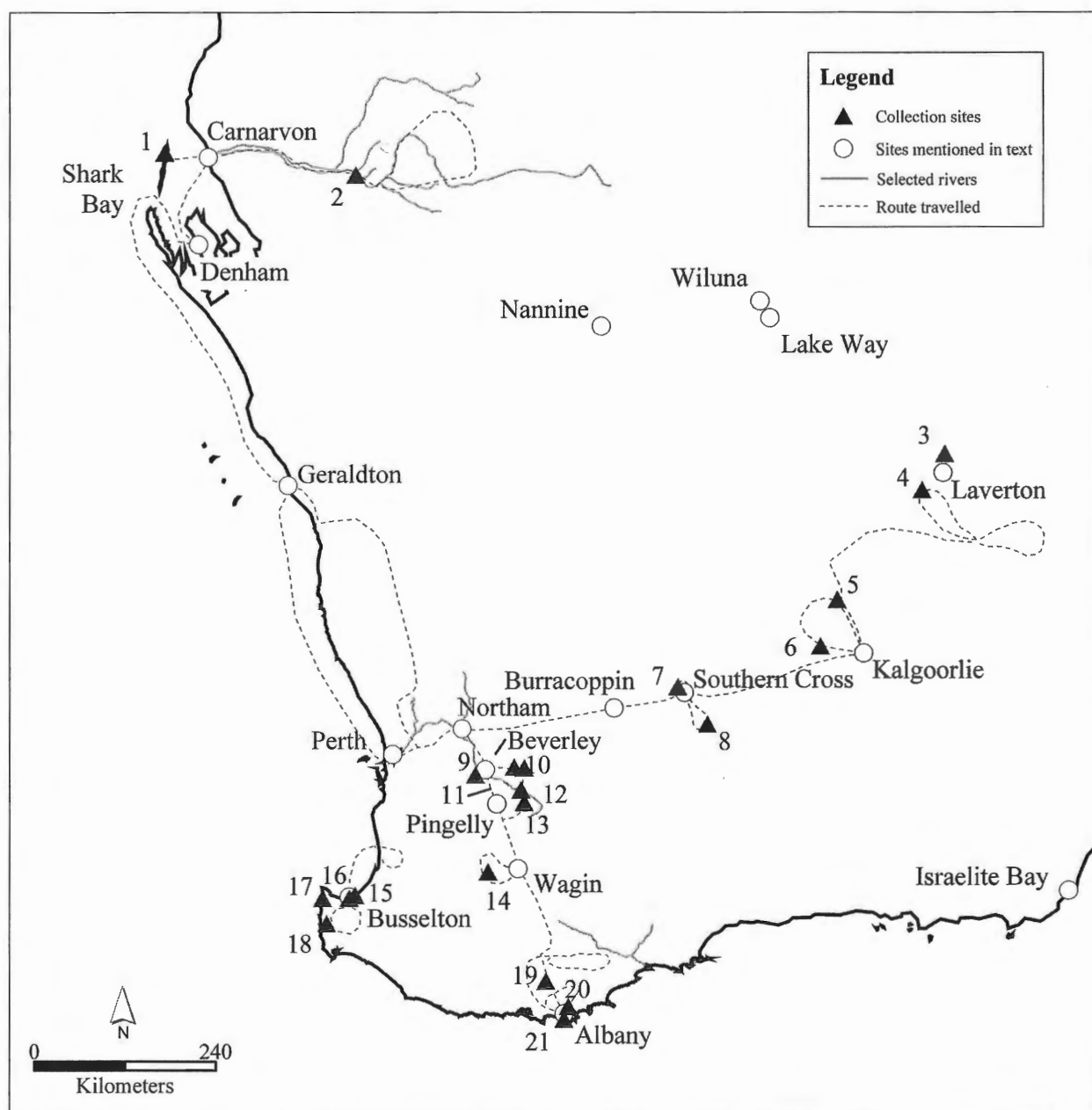


Figure 1. Map of the southern Western Australia showing sites mentioned in the text (○) and collection sites (▲); 1 – Bernier Island; 2 – Clifton Downs; 3 – North Pool; 4 – Hawks Nest; 5 – Jaurdi Hills; 6 – Kurrawang; 7 – Crookerdine Lake; 8 – Parker's Range; 9 – Boyadine; 10 – Stock Pool; 11 – Dwaladine; 12 – White Well; 13 – Woyaline Well; 14 – Arthur River; 15 – Wonnerup; 16 – Beachlands; 17 – Yallingup; 18 – Margaret River; 19 – Mt. Barker; 20 – King River; 21 – Big Grove. Shortridge's route in Western Australia is shown from a map accompanying one of his letters.

animals through to dingoes. He consulted extensively with Mr Bernard Woodward (Director of the Western Australian Museum) and John Tunney, a collector employed by this museum, to establish collecting localities where he might obtain the full range of possible species^{9, 15, 18, 20, 21}.

After leaving Albany his preference was to camp out away from major settlements and farms: "I find it is better to camp out than to stop on farms, as I can get away from houses to places that have not been hunted and where plenty of game is"⁹. The emphasis from London was to get a complete collection of mammals (at least one specimen of everything) and Shortridge was especially keen to collect *Potorous* and *Chaeropus*. Shortridge made considerable use of Aboriginal people and local Europeans, including the "many trappers"⁹, to assist his collecting. His collection of some species depended on the opportunistic collection by locals, particularly of those species not readily trapped or shot such as the honey-possum *Tarsipes rostratus* and the pygmy-possum *Cercartetus concinnus*. He made use of dogs also, which "are very necessary for hunting in this country. Of the three dogs poisoned at Wagin, two of them were very good terriers, which would put up bandicoots and wallabies, and could be relied on to point at trees where opossums lived"¹³. While in Laverton he hired the service of a local with kangaroo dogs to successfully hunt kangaroos.

Edited transcripts from Shortridge's unpublished letters

Albany and nearby sites "within a radius of about 40 miles"

Albany was a town of "4000 people"¹³ when Shortridge visited. His first specimens were sent from Albany on 11 March 1905 and included 7 possums sent to him from Mt Barker, "60 miles up the [railway] line"⁵. His stay in Albany included a "country expedition after seabirds"⁶.

"King River is about 7 miles from Albany and very much the same kind of country. The soil is poor and is not cultivated much. I shall stay here another month or so and then go about 90 miles up the line to a place called Tambellup where I shall be in grass country where the land is also more cultivated where I hear that animals that are either not found or rare down here are plentiful – as *Dasyurus*, anteaters, bandicoots, rabbit bandicoot (*Peragale*), pseudomice, and ring-tailed opossum. There are also two different kinds of wallabies from up there. ... where I am going to stay after Tambellup, where I hear dormouse phalangers are fairly common. I am trying very hard to get some *Tarsipes*. Several people around here know of them but there seems to be no way of trapping them. Pouched mice are evidently rare here, but the country around here is so thick with undergrowth that it is difficult to tell yet what is here and what is not"⁴.

He described *Perameles obesula* as "rare near the coast", *Sminthopsis murina* as "not plentiful, not easily caught in traps, found among dead wood under bark, etc", *Macropus brachyurus* as "very plentiful, but so many of the specimens obtained had mange or some kind of fur disease that only about one out of six are fit to skin", *Mus (fuscipes?)* as the "only plentiful bush rat, found in swamps", and *Mus musculus* as "plentiful and very large in size". His specimen of *Tarsipes rostratus* "was found at the bottom of a well and sent to me skinned. ... I was unable to find in what sort of places they are found in. They seem to be rare"⁵.

"I shall be about three more weeks about the coast. I have been going with a friend of mine who has a sailing boat. I have been very lucky with the water birds, especially waders, and have over 130 specimens for my new lot, mostly birds however as I haven't had much chance of getting mammals sailing along the coast, only a few wallabies and bandicoots. I got a third kind of bat the other day"⁶ [Shortridge obtained five species from the Albany area including the type specimen of the Southern Forest Bat *Vespadelus regulus*]. "There will be about 280 specimens of mammals and birds, mostly birds, as my last trip has been among the islets around Albany. ... The wallaby (*brachyurus*) that I have sent so many skins of simply swarms around Albany, being however about the only really plentiful mammal here except the house mouse, which has run wild, as I have trapped it in places ten miles at least from any house"⁷.

"I can understand about *Potorous platyops* and *gilberti*. I haven't heard anything about them from WA, neither has the Perth Museum, while they are both marked as coming from King Georges Sound"¹³.

Arthur River

"There is a very well defined coast belt extending about 25 to 30 miles inland [from Albany], which is generally low and rather swampy country, thickly covered with jarrah and red gum trees, with very thick undergrowth. On following the [railway] line, the country makes a sudden change at about Mount Barker, where the grass country begins. The country then remains very much the same as far as York, the white gum being the most plentiful tree. Instead of undergrowth it is all grass between the trees. The country up here is much easier to hunt in, as there are patches of undergrowth here and there where the animals collect. In this district there are lots of animals which are quite unknown around Albany. I was at the Arthur River, 20 miles west of Wagin, for the last fortnight. All the mammals and birds I got there were different to those around Albany. I got specimens of *Macropus eugenii*, *Onychogale lunata*, *Peragale lagotis* and *Bettongia lesueuri*, while I heard that anteaters, *Dasyurus* and *Chaeropus castanotis* were plentiful around the district. ... The bandicoots near the coast seem to be much smaller than the up country ones. One that I got last week at Wagin being three times the size of any I have sent from the coast. They are unsatisfactory things to skin, the skins being tender but very thick and difficult to dry before beginning to get rotten. There are so many trappers about that I am beginning to get a good idea of the distribution of most of the larger mammals. I think with the exception of *Pseudocheirus occidentalis*, I have obtained all the well known larger mammals about Albany"⁹.

Shortridge mentions several times that his stay at Wagin and Arthur River was brief. "The short time I spent at Wagin can hardly be content as far as the mammals are concerned. Those I sent from there being merely a job lot collected while I was waiting about"¹³. "Only I didn't stay longer [at Arthur River] as the same things will probably be found around York"⁹. "I intended going to Kojonup if possible, as I hear *Conilurus mitchelli* and several of the *Phascogales* are to be found there"¹³.

Beverley (Dale River, 20 miles west; Stock Pool, 30 miles east and White Wells, 45 miles east)

"I have stopped at Beverley as it is a smaller place than York and I won't have to get so far out of the town as I would at York, as up here there are farms and cultivated ground for miles around. ... There will be enough for me to do around Beverley for at least six weeks. I am going to stop at two places – east and west. West there are some swamps about 20 miles out, said to be in very good game country, and east, there are hills and sand plains, where I hope to get jerboa rats [*Notomys*] and rock wallaby. The reason I expect why I haven't got any jerboa rats is that I have only hunted up till now in heavily timbered country"⁹.

"... Beverley and Northam being grass country (that is between the trees) ... the common grey one [kangaroo] is plentiful there. ... My man [J.W. Bell] has gone on ahead to fix up a camp at County Peak about 30 miles east of Beverley where we hear there is a good deal of undisturbed game. You were speaking about the striped bandicoot [*Perameles bougainville*] and *Chaeropus*. I expect to get the first sooner or later in the South West, but from what I can tell *Chaeropus* seems to be very rare over here."¹³

"I have left my camp on the Dale River near Beverley and am before leaving the town, camping at a place east of the town where there is a large camp of blacks whom I hope to get skins from. The Dale River wasn't much of a place for mammals, being too much under cultivation"¹⁴. "I had gone to the Dale River 16 miles west of Beverley but the country there and furlongs right away to the coast is too much under cultivation for getting numbers although the few I did get there being nearly all different, gave an idea of what had evidently before settlement been equivalent to good game country"¹⁵.

"Unfortunately the wells [White Wells] were already on the point of drying up and the water was very foul. There was a small camp of natives there and they were leaving for the same reason – so we went with them to the next waterhole 15 miles west called Stock Pool, where we've fixed up a camp, by the way. The great drawback of this country especially in the summer is the scarcity of water. There are no rivers as far as this inland and water holes are very few and far between, and without a native guide they would be impossible to find. Even the Dale and Avon Rivers around Beverley are dry in summer. Only a series of pools with cultivated country for miles around them.

Anyway, once at Stock Pool it was a pleasure to at last get animals in the traps. We were there nine days and within that time with the help of the natives got 55 mammals and 12 birds. ... I got five specimens of a kind of *Conilurus* [*Notomys*] that I suppose will be *mitchelli* which seems to be the only kind found in the S.W. Also 11 specimens of *Mus* (*albocinereus*?). *Mus musculus* is on its way here however as I caught one in the traps the other day. ... The country we have been camping in is not far from the rabbit fence that extends from Sharks Bay in the north west – inland and then down through Burracoppin on the Kalgoorlie Line, then south to Israelite Bay in the south. Then is a lot of open sandy country, where I got the mice, and a fair lot of thick scrub. The natives are fairly intelligent and I've got an idea what to get there"¹⁵.

Brookton / Pingelly (Dwaladine, 20 miles east of Brookton; Woyaline, 20 miles east of Pingelly)

"I started out east of Beverley about 40 miles and then have been going south and am camped now about 20 miles east of Pingelly. It has been very hard work moving about as transport is so difficult. I have had to depend entirely on meeting blacks and getting them to move me – to take me to game districts. We have been most wonderfully lucky with mammals and since I left Beverley have got 270 odd specimens of mammals, not counting birds, including large series of *Conilurus* (*mitchelli*?), *Mus albocinereus*, *Petrogale* (*lateralis*), *Macropus giganteus*, *irma*, *eugenii*, *Onchyogale lunata*, *Lagostrophus fasciatus*, *Bettongia penicillata*, *lesueuri*, *Peragale lagotis*, *Perameles obesulus*, *Trichosurus vulpecula*, *Dasyurus*, *Myrmecobius*, *Hydromys*, six or seven or eight kinds of bats. I got into Pingelly last night – here have had a very difficult time, for want of stores and have been living on possums and kangaroo rats etc. fairly well ever since we left Beverley. The only stores we hadn't run out of long ago being flour and tea and sugar"¹⁶.

"The Eastern Districts have proven unfailingly rich in game of all descriptions, especially when compared with the other places I have been collecting in before in this country – having got more specimens here than in all the other places put together (of mammals)"¹⁷.

"I got some natives together and started out again, and during this whole three months we have had to depend eventually in getting about on their horses and carts, what it turns out that they have patched together from bits of discarded drays etc. The country was really everywhere terribly sandy and the rate of travelling was never more than about two miles an hour, and the weight of luggage had to be cut down to such an extent that boxes for keeping specimens in were out of the questions and therefore the means of keeping the larger specimens at all in shape was very difficult. ... We took nearly a week in getting to our first camp, which was a place where the natives said we were sure to get plenty of game. We had to get there in a very round about way as the country was so thick in so many places. A lot more natives joined us there but we had to get rid of most of them as they are a lot of bother always begging for stores of which of course we have taken as little as possible. In fact, running out of stores has been perhaps the worst difficulty, i.e. we had to practically do without everything except flour, tea and sugar, and depend entirely on what we got in the bush for the rest. Luckily there was so much game about that we were never seriously stuck. At the camp we got plenty of *Conilurus* and *Mus albocinereus* and a fair number of Kangaroos, Wallabies, chiefly *giganteus*, *irma* and *eugenii*, and a nice series of bats, several of which I haven't sent before [presumably Gould's wattled bat *Chalinolobus gouldi* and the Southern free-tail bat *Mormopterus planiceps*]. We were there about a month and then started south again to a place called Woyaline, chiefly to get *Lagostrophus fasciatus* which the blacks had described from there. In fact, some of them went while I was at the first camp and got some to show me. This was an even better place than the last. Small mammals were scarce, but I got a large number of different kinds of wallabies, *Myrmecobius*, *Dasyurus*, *Peragale*, bandicoots, etc. The *Dasyurus* especially were very plentiful here, and I was glad to get so many, as

they seem to be getting very scarce in a great many districts. The country here was very different to that at the last camp, being more open, Dwaladine being heavily wooded. ... I didn't manage to get the first [*Phascogale penicillata*]. The blacks say it is more plentiful nearer the coast - but I got the second [*Perameles bougainville*] - only one specimen which was caught in a big gin trap and rather cut about"¹⁷.

"We twice had to move on on account of bush fires. These fires I think further account for the scarcity of small pouched mammals in these grass districts. Most of them seem to live in hollow logs and trees, and I don't see how anything with these habits could possibly live through a bush fire which always burns up every dead stump or stick on its way when passing through a country. In some districts I've even seen possums driven to the top branches of trees in the daytime to get away from the fire"¹⁷.

"There were a few dingoes about and I trapped for them a good deal. But the natives told us from the first that we'd never trap them in this district on account of the number of kangaroo rats. Any track along which a dingo might go once during the night would be used also by numbers of the rats. Consequently however carefully we might bury and set the traps they were always being set off by and catching kangaroo rats. They were so plentiful here to be a great nuisance, always getting into and setting off the smaller traps set for mice etc"¹⁷.

"As you noticed a lot of people who bring me in animals are very fond of giving them a crack across the head, breaking the skull. I have a great bother to get the natives out of it, as their first idea when they've got an animal is to kill it, no matter how. But the smaller ones are very often broken by the spring traps that have an awkward way of often just catching things just below the head. I don't care for the wooden spring traps much. The circular spring wire traps are far the most successful. At the same time what is badly wanted in a hot country is a small trap, for catching the smaller mice and rats alive, for several reasons. When a lot of traps have been set over a good range of country, no matter how early one gets to them, the sun will have generally got on some of them. By this time they have all been cooked and as such they don't last half an hour in the sun getting rotten in an incredibly short time. Also you would hardly believe how many *Conilurus* and *Mus albocinereus* I have had to throw away on account of the ants. Lots of them work all night and as soon as a small thing gets caught they find it out, and next morning when I go to the traps I find half of them with hair on noses eaten off. Sometimes the whole thing is almost a skeleton. For the same reason we can't try baiting with meat for pouched mice, which however will taste the bait. A good thing for an all round bait I have found is a mixture of pollard and dripping. Ants don't seem to attack it and it does not get dried up by the sun in the dry time"¹⁷.

Southern Cross (Crookerdine Lake, 4-5 miles north; Parkers Range, 30 miles south)

"I have been at Southern Cross for a week ... I am camping for a fortnight about four miles north of the town, and after that, am going with a prospecting party to Parkers Range about 30 miles south. I don't think the country around here will be very good as everything is so

salt - all the lakes and flat country, and there are no hills nearer than Parkers Range. There is no fresh water here and the town gets its supply from Kalgoorlie"⁸

"I am afraid Southern Cross is a very poor place for mammals. I believe the chief reason is that the country is strictly desert, with a powdering of salt over everything. Even the rabbits that have got here do not increase. It is a funny thing that *Mus musculus* swarms everywhere, wherever I've been in W.A. miles from houses, and they seem to gather together at irregular intervals and go through certain districts like locusts. I heard of an instance quite lately in South Australia. I suspect this habit they have accounts to a great extent for what one hears of swarms of mice in Australia. Wherever I have camped so far they have collected around the camp"¹⁰. "I and a friend who is coming on this trip with me camped for a fortnight at Crookerdine Lake, about five miles north [of Southern Cross] and afterwards for a fortnight at Parkers Range, 30 miles south. The lakes and mountains marked on the map are very misleading. All the lakes are salt, a good many of which have water in them only during wet seasons, and then only a few inches in depth, and whether full or not, they don't seem to attract mammals or birds.

Parkers Range, I found out when I arrived there, was only the name of a gold reef, the highest point not being 200 feet above the surrounding country. I think on the whole we did fairly well, getting over 190 birds and mammals. ... The echidnas seem to be very rare here, as no-one here seems to have even seen them in the district before I found them with traps. ... I am sending off mice, but think they are probably *musculus*. They spoil any chance around here of trapping any other things as they get into the traps wherever they are set, being just as plentiful at Parkers Range 30 miles from any house as at Crookerdine Lake. Rabbits are also getting plentiful here. They were unknown in the district two years ago"¹¹.

"When I left Parkers Range some miners near where I was staying told me that there was a pouched mouse [*Cercartetus concinnus*] from there but that it was very rare and the only ones they had ever seen had fallen down empty shafts. I have lately had a letter from one of them saying that they had got one waiting for me at Southern Cross. These small marsupials are very difficult to make sure of getting, being arboreal and insectivorous, therefore neither leaving tracks or taking baits, and one can only as a rule get them by chance. ... I do not think there can be any native rodents in this kind of country as it would have been impossible to miss them over in the traps altogether and they are not difficult things to get where they occur, and all the time I was in Pondoland collecting, I never noticed any native mice that did not leave a well marked track. Also there are no mouse holes (the common mouse living in hollow trees and other places). ...

The country here swarms with lizards of every description, the larger kinds of *Varanus* being a very great check on the rabbits, following them down their holes like ferrets and feeding on the young ones. The country up here swarms with bats, especially around Kalgoorlie. They seem to hide by day in hollow trees though I didn't find any in the day time"¹³.

"The country around Southern Cross is perfectly flat and made up entirely of two kinds of country: gum forests and salt bush flats. The coast country where fresh water and mammals are plentiful ends a little way beyond Northam. At the Cross the gum forests change to what are called desert gums, which have a dry and a half dead appearance with no undergrowth, which however is replaced everywhere in the forest country, by a network of dry dead sticks and branches. This country keeps the same as far as Kalgoorlie, where the timber is thicker and even more dead looking. In fact, there are few trees that are not half made up of dead wood. *Macropus rufus* is the only kangaroo from around Southern Cross ... The only two mammals plentiful on the coast that seem to extend inland at all are *Peragale lagotis* and *Mymecobius*, but even these two are scarce as to be almost unknown. The Perth Museum has an anteater sent from Coolgardie, and I heard that two had once been caught at Laverton. It must be very rare as it is a diurnal animal and not at all shy. ... *Peragale lagotis* is more difficult. It is badger like in its habits and traps have to be hidden very carefully in order to catch it. It is also plentiful near the coast. It is not uncommon at Southern Cross, only as the rabbits have got there in large numbers, and their burrows being very similar. I caught a good many rabbits before getting the one I did. They are very bad skins to preserve, the skin being very oily. The trappers always discard them when caught for this reason. I couldn't find any traces of them at Kalgoorlie but was told of two having been caught in rabbit traps near Laverton, where they must be rare as they were shown around the town. ... There seems to be no other kind of kangaroos [other than red kangaroos] or wallabies known up here, which is easily accounted for apart from there being no water by there being no cover for them"¹³.

Kalgoorlie (Kurrawang, 60 miles north and Jaurdi Hills, 33 miles west)

"A private [railway] line runs there [Kurrawang] for supplying timber to the mines, and the manager has offered me the use of the line, and it seems to be just a nice distance out of the town"¹¹. "I shall be glad to get to a better place for mammals. Except for bats there are practically none here, and everyone in the district says the same thing. It is about the middle of the salt district and not far enough inland for any mammals that may live in the interior. The only things that there are being a few stragglers from the coast and even they are so scarce that the fact of an opossum being caught here some while back appeared in the West Australian paper in which it draws attention to the scarcity of mammals on the fields. I think I have seen tracks of *Peragale lagotis* but the burrows are very difficult to tell from rabbits. Anyhow, I haven't been able to trap one yet. ...

The country up here is not for the most part open country as most people would think, but heavily timbered in many parts, the trees being rather more stunted than near the coast, and there is very little undergrowth. I am in the timber line that runs close to the Jaurdi Hills which supplies the Kalgoorlie mines with firewood. I have been a lot among the wood cutters and they all agree in saying that they have never seen while chopping down trees, any kind of small mammals, even mice, except for bats, which often come out of the hollow trees. Even the house

mouse, so common at Parkers Range, has not come here yet, and the common brown and black rats have never been known on the fields. It is supposed for some reason that they would live here. They are common enough on the line between Perth and Albany"¹².

Laverton (North Pool, 10 miles west; Hawks Nest, 12 miles south-west)

"From Kalgoorlie to Laverton the country begins to change – mulga scrub taking the place of gum forests. Mulga trees can only be compared to giant sage bushes, between 10 and 20 feet in height, being semi-transparent networks of sticks with small greyish blue leaves on the tops. Around Laverton the country is chiefly mulga scrub, salt bush and spinifex, or porcupine grass. The Spinifex is sandy country with Spinifex grass dotted in little clumps all over it, so prickly that horses cannot travel far in it. It was however the only kind of country I have been in yet (inland) that looked at all likely to have mice or rats in it, but it turned out no better, except that in the Spinifex about a hundred or so miles north towards Lake Way there is a small kind of *Conilurus*. It was known about at Laverton as one had been brought down from there and kept for some time in spirits by the Chemist there. ... The country is not so salt and fresh water can be obtained in a good many places by sinking wells to a depth of 30 feet on average, but even up here there is no permanent surface water. I camped first about ten miles from Laverton for three weeks at a place called the North Pool, which is considered the most permanent surface water south of the Lake Way district, but it is a particularly dry season, and when I got there it was a mere puddle about 30 feet by 10 wide and by the time we had left it had dried up. There is a well there as the district is good enough to run cattle on and water has to be pumped for them when the Pool is dry. Kangaroo did not seem to come to the pool at all, though emu did. I got two kinds of bats that I had not got before [the White-striped freetail-bat *Nyctinomus australis* and the type specimen of the Inland broad-nosed bat *Scotorepens balstoni*].

Then I moved to Hawks Nest, a deserted mine, where I learnt there was a man who had some kangaroo dogs. Kangaroos are still more or less scarce but although they were only as far as I knew the common red kind, I thought it better to get a few by some means, so I hired him and the dogs with the agreement that I'd give him specimens of any kangaroo we got. He managed to get nine. ... From information I have received there seems to be a species of rock wallaby, a small kind of ring-tailed opossum and this *Conilurus* near the Lake Way district. Lake Way itself is a salt lake but has a good many fresh water creeks running into it, and I hear that though it is occasionally very seldom dry and there is a track from Nannine to the Wiluna mine, so that that will be the best way to get to that part of the country"¹³.

Camarvon (Gascoyne River)

"The country all round here as far as one can see is perfectly flat sandy desert, which I hear continues the same right up the north west, with nothing but salt bush growing on it. ... The country is very salty and everywhere off beaten tracks it is more like trying to walk through brown sugar

than anything else I can think of, as one sinks into the sand at every step. ... The Gascoyne River, like most of the rivers and lakes out here, does not exist, except after up country rains, being a salt creek that runs in for a mile or two and then there is a dry river bed. The Murchison River I hear is the same. The farms inland have to rely entirely on wells or occasionally artesian wells, although most of the year there are water holes in places along the Murchison River, but at wide distances apart"¹⁸.

"The distribution of mammals in this part of the country is very curious as with all these wallabies on the islands off the coast. On the mainland they are entirely absent. There are a good many natives around here and they all tell me there are no wallabies of any kind. Whether they were ever here and have been killed off by dingoes or other means I don't know. To me it would seem that a more southern fauna had extended up to the islands while around Carnarvon was in the desert fauna area – which had reached to the coast. The only small mammal I have as yet heard of from around here is *Echidna* – although I expect *Mus albocinerus* will also be here. The Perth Museum has a very old specimen of *Perameles bougainvillei* from Sharks Bay (Denham). The blacks tell me that there is a bandicoot there but very few on the mainland – so that it probably gets more plentiful further south. ... but at some time during this trip I mean to go to Denham – there are blacks there so I hope to get it on Dirk Hartog Island or somewhere around there. As regards the wallabies being on the island and not on the coast I have been told by several people here that I won't get a wallaby on the coast south of Broome (which is well watered and tropical). I heard the Dampier's Archipelago is said to swarm with them (most probably *L. conspicuatus*) on looking up the books. The mainland form doesn't seem to have been found south of Roebuck Bay. At the same time it is funny that islands so far south of that as Barrow Island and Dampier Archipelago should have similar things with nothing in the coast country between"¹⁹.

"At the same time there appears to have once been a fauna in these parts corresponding with that on the islands. The old settlers all say that as late as 1880 wallabies were as plentiful around Carnarvon as on Bernier Island and the idea to everyone here seems to be the most acceptable way of explaining the complete disappearance of mammals which is that some epidemic probably to do with white settlement or the introduction of sheep killed them all off. The only things left being those which had a wide range inland, namely kangaroos, *Echidna*, etc which have since straggled back. I am told that they appear to have had a kind of marasmus – curiously about that time an epidemic of measles went through the N.W. which while being no more severe than usual among the whites almost exterminated the aboriginals – from which they have never since recovered in numbers. Although the wallabies were so plentiful on Bernier they were in a very poor and mangy condition looking almost as if some disease had hold of them. If so it is a great pity as they seem to be the only stronghold left for *Lagorchestes hirsutus* particularly which possibly is quite extinct on the mainland .. unless it is found in the north. I have since heard about a few still around Port Hedland"²⁰.

"Besides wallabies, possums once occurred around Carnarvon – they died off tremendously some years ago in the S.W. especially around settlements but have increased again except in the vicinity of towns during the last few years. Possum hunting almost stopped in the S.W. at the time they died off. ... I heard a vague report of one being found at the mouth of the Murchison but there is no way of getting there. I don't think they will be found in the north central districts as like other wallabies except in very well watered districts. They seem to be coastal, although I got a large series of *Lagostrophus fasciatus*. It is very local now in the S.W. I only heard of four locations for it on the mainland, around the Wongan Hills, East Pingelly, East Wagin and Salt River – it is probably dying out as it once had a wide range being said to have once been plentiful around Albany. There were plenty of blacks on the station I was on. They did not get me anything in the way of mammals and their stories of wallabies altogether agreed with those of the white settlers. ... If *Conilurus* occurs up there it must be migratory and irregular in appearance"²⁰.

Bernier Island (and Dirk Hartog Island)

"Mr Baston who owns Bernier Island just north of Dorre Island and in about four days time he is taking us there for three weeks or a month. There is a sheep station on the island and only one man on it. Baston is obviously one of the big men of Carnarvon, being the mayor and owning a store, etc. [see Carter 1987 for photos and description], and I believe he intends doing us well while we're here. I hear that there are plenty of wallaby on the islands but none at all on the mainland. It is curious, but at the same time there is no feed for anything here for them, while as there is feed for sheep on the islands that must be better country"¹⁸.

"The island is quite small, 16 miles by 3, sandy and covered for the most part and rather thinly with low scrub - very like the mainland. ... The two wallabies and *Bettongia* swarmed on the island. In the case of *Lagostrophus* I have never seen any animal not even rabbits (considering the small amount of area) in such numbers. It has been a particularly dry season and they were very thin. The feed was evidently insufficient for them all and dead wallabies were lying about in all directions. It would seem that they have no natural enemies on these islands and they have bred to such an extent that the island will carry no more and in times of drought a number have to die. *Lagorchestes* was not so plentiful. ... Dirk Hartog and Dorre Island are also said to swarm with wallabies. ...

The bandicoot's skull I found on Bernier Island will probably be this kind [*Perameles bougainvillei*]. I took a lot of trouble in trying to get a specimen of it, but haven't yet got one. There is a man on the island looking after a flock of about 60 sheep - he had five cats there and on a small island like Bernier they have perhaps thinned them out"¹⁹.

"I should have liked to have time to go to Dirk Hartog to try to get the bandicoot that I missed on Bernier. I hear the wallabies are dying off fast on Dirk Hartog and are only found now in the extreme north of the island. There

is a sheep station there which probably accounts for this. The Perth Museum has a very old specimen of *Perameles bougainvillei* marked "Sharks Bay" which probably came from the islands – Dorre Island I have since found out"²⁰.

Clifton Downs (east of Gascoyne Junction)

"... a large sheep station about 180 miles inland in the direction of Peak Hill. I hear it is the largest station in the north west – eight hundred thousand acres, extending right up to Peak Hill itself, belonging to a man called Fitz Patrick [see Battye 1913: 221-225 for a profile of the Fitzpatricks and their pastoral estates at 1913: Dairy Creek Station (408,000 acres) and Dalgety Downs Station (266,000 acres)]. I don't think I could possibly have got a better district than that will be for the north-western Kangaroos, etc. He tells me there are no wallabies. It is a funny thing wallabies don't even seem to extend very far from the coast, but there are plenty of blacks up there, and if there is anything to be found, I'll find out through them. At any rate several kinds of Kangaroos are up there and I hear they are very plentiful – chiefly red and some kind of Wallaroos, so I'll get a good look at them. I hear there are porcupines also"¹⁸.

"After waiting about in Carnarvon and having no luck with dugongs which was the only thing to get there I at last got on a team that was going inland. A dugong was caught while I was up country and the skull kept for me. Unfortunately it was boiled. The journey up country was very slow taking ten days to do 120 miles where I stopped at a station called Clifton Downs, the largest sheep station in the north-west said to be two million acres. The country however is so poor that the stock is very small compared with the size of the station. I went thirty miles further on with a nigger and pack horse for some of the time to the Wyndham Ranges after *Macropus robustus* (*cervinus*) locally called the hill kangaroo, but only managed to get three specimens of it. I got a good number of *Macropus rufus* which was more plentiful than I have seen it anywhere. As anything got on that trip had to be put on the pack horse, I had to roll up the larger skins as best I could. Beyond the kangaroos there seems to be practically nothing else, except odd specimens of *Echidna* and *Peragale lagotis* – both of which were very rare. There were hardly any bats around. Consequently this is chiefly a bird collection. From what everyone has told me and what I have seen of this north-west country, I don't think there is any mammal collecting to be done in any of the parts south of Broome, except on the islands. From Geraldton northwards as far as the tropical rainfall districts the whole coast is a flat stretch of sandy and stony desert with nothing but salt scrub growing on it. I have had talks with people from Onslow, Port Hedland and all the N.W. towns and they all tell me that there are plenty of kangaroos but nothing else and that I would have to get inland for the kangaroos even. Except on the islands there seems to be nothing in the way of wallabies south of Broome"²⁰.

Busselton and Margaret River

"I have decided to go south to Busselton which should be central for the small marsupials – *Phascologale* etc – which I haven't done well in. I may also be able

to get *Pseudocheirus* and hear that dingoes are more plentiful there than anywhere in the S.W. There are lots of caves which should be good for bats and I have also heard of a small variety of the grey kangaroo which sounds like *melanops* which if so doesn't seem to have been found in W.A."²⁰.

"As I suppose this will be my last camp in WA, I am trying to get together as many mammals as possible that I have not yet sent or have only sent a few of. The chief things that I am after here *Pseudochirus* and *Phascologale penicillata*. I have already got two of each. One of the *Pseudochirus* and the two *Phascologales* were got by a trapper who unfortunately did not keep the skulls, but Mr Woodward has promised me a specimen of each which will probable have skulls and there is every chance of my getting more here before leaving especially *Pseudochirus*. This is a fairly good place for mammals and besides those two I have got specimens of *Macropus brachyurus*, *eugenii*, *Trichosurus vulpecula* (black and grey), *Hydromys*, *Dromicia* (1 sp) and a good number of bats, *Dasyurus* etc and while I was in Perth the Museum gave fine specimens of *Tarsipes*, 2 *Sminthopsis murina*, 2 *Dromicia*, 1 *Phascogale* sp and I have been promised 1 *Pseudochirus*, 1 *Phascologale penicillata*, *Mus fuscipes* (from island off Esperance) and several other things in exchange for things that I sent from Beverley. I want before leaving here to get some specimens of the dark variety of *Macropus giganteus* and the dingo. It is curious how frequent melanism is near the coast. The two *Pseudochirus* got here are black varieties, while about one in every half dozen of the common opossum is black. ... I believe a *Potorous* is still here but very rare however. I am going to try my best to get one and have got everyone in the district on to it. Unfortunately there are very few natives here and they are all working for white people. They call the animal "Wurrark" and doubt whether I will get one."²¹.

"I am enclosing a ... list of what I got from the Margaret River district. The bats all of which I haven't seen, will be nearly all spirit specimens as I have been obtaining these by leaving bottles of spirits at various places – one house at Busselton I hear has got 40 specimens for me. I hope that they will include several kinds. Besides the list I have also various animals from the Perth Museum: *Tarsipes*, *Dromicia*, *Sminthopsis*, *Phascologale*, etc. ... Counting specimens of the Perth Museum, I shall be sending about 150 mammals, 34 birds and 53 odd skulls, of the following animals picked up in or near the Margaret River caves: *Phascologale* (2 species), *Dasyurus*, *Isodon*, *Pseudocheirus*, *Trichosurus*, *Macropus giganteus* and *brachyurus*, *Canis dingo*, *Mus* sp. ... I am also sending 6 skulls that I am wondering if are *Potorous*."²².

In a subsequent letter²³, he included the following listing of species: *Macropus giganteus*, 12 *M. brachyurus* plus additional skulls, 8 *M. eugenii* plus 2 foetuses, 5 *Bettongia penicillata*, 6 *Potorous*? skulls, 5 *Tarsipes spensera*, 3 *Dromicia concinna*, 11 *Pseudochirus occidentalis* (grey), 4 *P. occidentalis* (black), 7 *P. occidentalis* odd skulls, 8 *Trichosurus vulpecula* (grey), 10 *T. vulpecula* (black), 1 flat skin, 3 *T. vulpecula* odd skulls, 5 *Dasyurus geoffroyi*, 1 *D. geoffroyi* odd skulls, 1 *Phascologale (apicalis?)*, 2 *P. penicillata*, 1 *P. penicillata*

fragments of skull, 4 *Isoodon obesulus*, 3 *Isoodon obesulus* skulls, 3 *Sminthopsis murina*, 1 *Canis dingo*, 3 *C. dingo* skulls, 1 *Mus rattus*, 3 *M. musculus*, *Mus* sp fragments of 24 skulls, 4 *Hydromys fuliginosus*, 1 *Nyctophilus timoriensis*, 3 *N. geoffroyi*, 70 *Chalinolobus morio*, and 1 *Thylacomys lagotis* (from Watheroo, Midland railway) flat skin.

"The Perth Museum people have been very nice to me all the while I've been here and Mr Woodward has allowed me to pick out anything I thought you might want from the duplicates of the Perth Museum. Among others a specimen of *Phascogale calura* of which he only had two specimens and *Perameles bougainville* and *Sminthopsis crassicaudata* – each of which he only had three of. I am enclosing a list of what he has given me, which I am sending on to you. ... The Museum is very small and they seem quite anxious to send a lot of their stuff home."²⁴ His list included: "2 *Phascogale apicalis* (Kojonup, SW), 1 *P. calura* (Kojonup, SW), 1 *P. flavipes leucogaster* (Kojonup, SW), 1 *P. pericillata* (south-west), 1 *Perameles bougainvillei* (Darton, SW), 1 *Myrmecobius* (SW), 2 *Petrogale lateralis hacketti* (Mondrain Island off Esperance), 1 *Macropus eugenii* (Middle Island, east of Esperance), 1 *M. eugenii* (Twin Peak Island off Esperance), 1 *M. brachyurus* (Bald Island, east of Albany), 1 *M. brachyurus* (Rottne Island), 2 *Mus (fuscipes)?* (Mondrain Island off Esperance), 1 *Sminthopsis crassicaudata* (Central South Australia, north of Adelaide), 1 *Pteropus funereus* (Northern Territory), 1 *Acrobates pygmaeus* (Eastern States), 1 *Mus norvegicus* (Perth), 4 *M. rattus* (2 albinos) (Perth), 1 *Canis dingo* (WA), and several immature rodents from Port Darwin in spirit.

Other localities – Eucla, Barrow Island, and Kimberley

"I have heard very bad accounts of Eucla - the rainfall is less than up here [Carnarvon] even – the place is said to be a flat desert with no fresh water and simply eaten out by rabbits. But I shall find out more about that when I go south. There is a telegraph station there now and boats only call there every three months to leave provisions – you see it is not nearly far enough east to get into the South Australian fauna which begins in the lake district and too far east to get much from W.A. as it is outside the southern rainfall area which ends just beyond Esperance. If I go I shall have to stop three months whatever the place is like and a man who I met who was once there tells me that beyond the odd straggler of red kangaroos there is nothing to get but rabbits. ...

Barrow, together with the adjoining small islands, seems to have the northern fauna – *Lagorchestes conspicillatus*, etc. – From Broome northwards I hear that, as in the S.W. districts, small stuff begins to get plentiful. ... I met a man called J.P. Rogers [see Whittell (1954) for a profile of Rogers] who is doing an overland trip from Derby to Wyndham in March (he has done the trip before and knows the country). ... he has done a lot of collecting chiefly live stuff for zoos and dealers. ... he has great knowledge of the mammals of this country chiefly in the north ... He tells me that many of the smaller things are getting exterminated even up there. *Onychogale unguifera* is evidently the plentiful of the wallaby up there and *Petrogale* is plentiful in certain localities to the north of Derby. Also *Dasyurus hallucatus*, also a *Phascogale* that he believes to be *pericillata*, which doesn't seem to have been

recorded from the N.W. He knows all the kangaroos and tells me that *isabellinus* is found around Wyndham which seems very far north however. Also he tells me of a large grey kangaroo in the country north of Derby which he says is more like *giganteus* than any of the wallaroo tribe which seems to be the general run of kangaroos up there. *M. rufus* he tells me does not extend as far north as Broome when its place is taken by this grey species of an *agilis*"²⁰.

Profile of areas visited by Shortridge

Table 2 provides a profile of the land use, stock numbers, and number and proportion of the adult population engaged in pastoral pursuits for areas visited by Shortridge. Stock numbers were highest in the Gascoyne district (580,449 sheep and 34,657 cattle) but densities were low (7 km⁻²) compared to the more mesic areas of York (41 km⁻²) and Katanning (36 km⁻²). Other areas, such as Yilgarn and Coolgardie in the east and Sussex in the far south-west, carried negligible numbers and densities of stock. Mining was the dominant land use in Yilgarn, Coolgardie and Mt Margaret, reflected by the low percentage of the adult workforce engaged in agricultural and pastoral pursuits. The area cropped was at a maximum in York (8.4% of district area) and Katanning (6.6%) and was less than 0.5% in all other districts.

Assessment of fauna

Table 3 summarises the number of native critical weight range mammal species collected by Shortridge in five regions together with the number of mammals believed likely to have occurred in that region, but that were not collected by Shortridge. There were significant differences in the proportions of the original fauna collected by Shortridge across the five regions ($\chi^2_4 = 25.61$; $p < 0.01$), varying from high of 81% at Avon River and surrounds to lows of c. 10% in the semi-arid Gascoyne and Goldfields. The faunas of the mesic sites (Avon River, Margaret River (62%), and Albany (47%) regions) apparently were substantially more intact than were the semi-arid regions (Goldfields (14%) and Gascoyne (8%)) at this time.

Shortridge collected 65% of marsupial and monotreme species that are now believed to have once occurred in the areas in which he collected and 45% of rodents (Table 4). This difference was not significant. The absence of rodents was particularly marked at the semi-arid Gascoyne and Goldfield sites and their absence was expressly remarked on by Shortridge at some sites. He collected no *Leporillus*, no *Notomys* other than *N. mitchelli*, and no *Pseudomys fieldi*. He was unable also to collect a number of smaller species of *Pseudomys* and dasyurid (*Sminthopsis* and *Antechinus*) that might have been expected to have occurred there.

Discussion

Strengths and limitations of Shortridge's collections

Shortridge spent some 2½ years in intensive collection in southern Western Australia. He was able to collect the type specimens of species such as the heath rat *Pseudomys shortridgei*, the Inland broad-nosed bat *Scotorepens balstoni*

Table 2. Profile of population and land use for districts in 1906 visited by Shortridge (Government Statistician's Office Perth 1908).

Magisterial district	Primary land use in 1906	Agricultural and pastoral labour (as % of adult population*)	Area of privately owned land (acres)	Area of leasehold land (acres)	Sheep numbers (number per 100 acres of private + leasehold land)	Cattle numbers (numbers per 100 acres of private + leasehold land)	Area cropped in acres (% of private + leasehold land in district)
Plantagenet (includes Albany)	commercial / agricultural	481 (12)	355,106	543,600	74,197 (8.3)	3,130 (0.35)	2,221 (0.25)
Katanning (includes Arthur River)	pastoral / wheat	1,724 (67)	1,350,848	15,840	194,410 (14.2)	4,788 (0.35)	90,384 (6.61)
York (includes York, Beverley, Brookton, and Pingelly)	agricultural	1,574 (56)	1,208,256	267,483	240,391 (16.3)	3,449 (0.23)	124,292 (8.42)
Sussex (includes Margaret River, Busselton and Bunbury)	forestry / agricultural	239 (23)	108,926	397,320	5,636 (1.1)	6,491 (1.28)	1,585 (0.31)
Yilgarn (includes Southern Cross)#	mining	2 (< 0.1)	2,371	161,347	417 (0.25)	190 (0.12)	35 (0.02)
Coolgardie (includes Kalgoorlie)#	mining	12 (< 0.1)	925	362,708	1,381 (0.38)	882 (0.24)	27 (< 0.01)
Mt Margaret (includes Laverton)#	mining	93 (1)	17	2,775,198	11,040 (0.40)	7,497 (0.27)	0
Gascoyne (includes Carnarvon and Clifton Downs)	pastoral	897 (57)	3,716	21,229,570	580,449 (2.73)	34,657 (0.16)	30 (< 0.01)

* adult population based on number registered on Roll of Legislative Assembly, which uses different boundaries to magisterial district. However, the range in percentages between districts provide an indication of the relative importance of agriculture and pastoralism to the local economy.

the Yilgarn Goldfields were proclaimed in 1888, and Southern Cross, Coolgardie, Kalgoorlie and Laverton were established in 1890, 1893, 1894, and 1900 respectively (Jarvis 1986).

and the Southern forest bat *Vespadelus regulus*. He made use of incidental collections by settlers, the intensive trapping by professional trappers, and collections by Aborigines. He caught many more animals of some species than are recorded: "you would hardly believe how many *Conilurus* and *Mus albocinereus* I have had to throw away on account of the ants."

Shortridge's ability to collect specimens of all species present at any site may have been limited by a range of factors. Shortridge had a horse and trap to get about at sites such as Albany, Arthur River, Brookton and Pingelly. However, at sites that he accessed initially by rail, coastal steamer, or by wool carting team (Carnarvon, Clifton Downs, Southern Cross, Kalgoorlie and Laverton) it is unclear how readily he was able to move away from the immediate area of his camps. Hence, it is possible that the lack of mammals at the semi-arid sites may, in part, be due to limited sampling effort as the low densities of many species means that disproportionately more time and effort are needed to reliably collect all species.

He had difficulty in obtaining some species (e.g. *Tarsipes* and *Cercartetus*), due to a lack of understanding of their ecology and habitat preferences and because they were not readily attracted to traps. At some sites he had difficulty trapping some species because of the extreme abundance of other species, effectively saturating his traps. He complained of house mice at Southern Cross and rat kangaroos to the east of Beverley limiting his ability to catch other species.

Shortridge specifically mentions the use of Aborigines at Pingelly and Brookton and at Clifton Downs, but they may not have been good sources for small mammals that were unlikely to have been a significant food source for them (e.g. *Sminthopsis*, *Antechinomys*). Shortridge's trapping technology may have been somewhat limited for the capture of some species of small mammals, compared to that used 100 years later. For example, McKenzie *et al.* (2000) obtained at least four species of small mammal at their Gascoyne Junction site, to the west of Shortridge's Clifton Downs. These were *Antechinomys laniger* in invertebrate pitfalls filled with glycol-formalin and left *in situ* for 12 months, and *Notomys alexis* and two species of *Sminthopsis* in deep, narrow pitfall tubes.

Shortridge describes dry conditions at Laverton in October and November 1905 and on Bernier Island in mid-1906, perhaps impacting on captures at these sites. However, rainfall at neither site was low when viewed against the long-term rainfall records. Rainfall at Laverton in 1905 was 262 mm compared to a long-term median of 196 mm (Bureau of Meteorology records). Rainfall at Denham (the nearest long-term recording station to Bernier Island) in 1905 was near average (233 mm compared to a long-term mean of 228 mm), but was low in the first half of 1906 (53 mm cf. 146 mm). Conditions were particularly dry in the inland Gascoyne in 1905 (just 88 mm in 1905 at Mount Augustus Station) and early 1906 prior to Shortridge's collections in September-October 1906.

Table 3. Collections of native critical weight range mammals by Shortridge compared with the number of mammals not collected whose current or historic range overlap his collection locations. Data are from Appendix 3.

Location	Number of species expected to occur	Species collected	Species not collected
Albany and surrounds	15	7	8
Margaret River and surrounds	13	8	5
Avon River and surrounds	21	17	4
Semi-arid Gascoyne	12	1	11
Semi-arid Goldfields	14	2	12

Table 4. A comparison of the terrestrial marsupials and native rodents collected or missed by Shortridge. Data are from Appendix 3 and Appendix 4.

	Total number of species expected to occur	Species collected	Species not collected
Marsupials*	40	26	14
Rodents	11	5	6
Total	51	31	20

* includes the monotreme *Tachyglossus aculeatus*

Pattern of decline

Four important generalisations can be made about the pattern of decline of the fauna from Shortridge's collections:

- An absence of all but a few terrestrial mammals in the arid and semi-arid zones. This decline appeared to be common to both pastoral (Carnarvon, and Clifton Downs) and non-pastoral districts (Southern Cross, Kurrawang, Jaurdi Hills, and Laverton).
- An abundant and species-rich fauna extant in at least some areas of the mesic south-west (Arthur River, east of Beverley and Pingelly, Albany and Margaret River).
- A lack of fauna in the immediate vicinity of areas in the mesic south-west where agriculture was well developed (York and Beverley).
- Regional patterns of decline that were broadly consistent for both marsupials and native rodents. In contrast, bats and the one species of monotreme remained abundant.

Shortridge identified a major decline in the arid and semi-arid zone fauna that appeared to be general to all terrestrial species other than the large kangaroos, echidna *Tachyglossus aculeatus*, and to some extent, the bilby *Macrotis lagotis*. He noted the contraction of possums and bilbies from the semi-arid zone in the years immediately prior to 1906 (Shortridge 1909), specifically mentioning the loss of possums from the Carnarvon district.

Facey (1981) made an extended trip on horseback from Mullewa to the Ophthalmia Range in north-western Australia in 1909, covering an area some 200 km to the east of Shortridge's Gascoyne site. The trip was a cattle drive, took six months, and meant camping at many locations. Facey recorded no mammals other than dingoes *Canis lupus dingo* and kangaroos *Macropus* spp., in strong contrast to his observations from the newly-settled farming areas to the south. Similarly, other observers (reported in Leake 1962) report the loss of marsupials in the Coolgardie area apparently at some time after 1878

and of rodents in the area between Southern Cross and Coolgardie prior to 1891. These declines were prior to declines in the Kellerberrin area, a more mesic area some 150–400 km to the west.

Richards and Short (1996) reported the early loss of at least some mammal species from pastoral areas on the Nullarbor. Species such as brush-tailed possums *Trichosurus vulpecula* and burrowing bettongs *Bettongia lesueur* apparently became scarce in the 1880s and 1890s, at a similar time to that reported for mammals in the Carnarvon area by Shortridge, and the Southern Cross and Coolgardie areas by Leake. However, in contrast to the widespread and early loss of mammals in arid and semi-arid areas visited by Shortridge, at least some medium-sized mammals (e.g. brush-tailed bettong *B. penicillata*) survived to the 1920s (Richards and Short 1996) and to the 1930s (e.g. western barred bandicoots) on the Nullarbor (Brooker 1977), beyond the 1930s in arid parts of northern South Australia (Finlayson 1958), and to the 1960s in the western deserts (Burbidge *et al.* 1988).

The past decline of mammals in arid and semi-arid parts of Western Australia detected by Shortridge was not evident at sites he visited in mesic woodland, scrub and forest sites, except in areas of closer settlement. In fact, he found that many species, soon to be extinct on the mainland, were so abundant as to be pests when trapping at woodland sites. For example, Shortridge reported that *Bettongia penicillata* "simply swarms about twenty miles east of Pingelly", *B. lesueur* was regarded as "very plentiful in most districts", tammar *Macropus eugenii* was "the most widely-distributed wallaby ...[and] collect together in large numbers", and *Trichosurus vulpecula* was "abundant and generally distributed" (Thomas 1906b). The bilby and the echidna were two of the few species to occur in both semi-arid and more mesic areas. The former was described as "more plentiful near the coast ... [and] to have become scarcer in the interior than formerly"; the latter as more numerous in the semi-arid interior (Thomas 1906b).

The continued abundance of fauna in the woodland sites in the early 1900s is consistent with the observations of

Facey (1981). Facey described the taking up of new country in 1902 in an area some 30-50 km south of Shortridge's collecting locality at Woyaline. At this time, Facey's farm was remote, taking three days for a round trip to Narrogin by horse and cart (Narrogin was 42 km away). His family subsisted for over three years by selling possum skins while preparing a 100 acre cropping paddock for planting. Comments such as "the first morning Uncle and the boys caught twenty two possums" suggest local abundance. He mentions the presence of dingoes, kangaroo rats *Bettongia* spp., and native cats *Dasyurus geoffroii* in the area. Another observer (P. Hall, pers. comm. to J. Short 1988) reported burrowing bettongs as being present at Kulyaling (halfway between Pingelly and Brookton) at some time after 1908 and shortly before the arrival of the rabbit. Their persistence in mesic woodland sites in Western Australia is consistent with the persistence of *Bettongia* in similar habitat on the western slopes of New South Wales (Short 1998).

Shortridge frequently cited the need to move well away from towns and farmland to obtain specimens. He recorded the hunting of native species as pests, for food, and for the sale of their skins, and clearing, cultivation, fire, and the impact of domestic dogs and cats. The impact of closer settlement is discussed in detail below.

Shortridge collected native rodents at many sites (water-rat *Hydromys chrysogaster* at Albany and Beverley, bush rat *Rattus fuscipes* at Albany, hopping mouse *Notomys mitchelli* at Stockpool, Dwaladine and Woyaline, and ash-grey mouse *Pseudomys albocinereus* at Stockpool and Dwaladine), but comments on their scarcity or absence at more semi-arid sites (e.g. Parkers Range, Jaurdi Hills, Laverton, and Clifton Downs) despite considerable effort spent in searching for them. Hence, both marsupials and native rodents appeared to show similar patterns of decline. Susceptibility to declines and extinctions appeared not to be taxonomically based (i.e. marsupial versus placental).

Possible causal factors

Shortridge expresses a range of views on the cause of decline of mammals that appear to be derived both from the opinions and observations of long-term residents and from his own observations and deductions of land use, wildlife, and the spatial and temporal pattern of their decline. He identified four causal factors in the decline of mammals in Western Australia: disease, predation by feral cats, the spread of house mice, and bushfires (see Table 5). In addition, closer settlement (cultivation, hunting, pest management, etc) was identified as a problem in causing local declines. Shortridge's collections preceded the arrival of foxes, and were at a time when "the rabbit has so far been kept out of the agricultural districts of the South-west by a rabbit-proof fence that passes through Burracoppin..... it seems to have spread everywhere east of the fence" (Thomas 1906b: 767). It was also at a time when pastoralism was localised and of relatively low intensity, and before significant land clearance for wheat cropping.

Disease

Shortridge was informed by "old settlers" of the Carnarvon district that as late as the 1880s "wallabies were as plentiful around Carnarvon as on Bernier Island and the idea of everyone here seems that the most acceptable way of explaining the complete disappearance of mammals – which is that some epidemic probably to do with white settlement or the introduction of sheep – killed them all off". He noted that many species (banded and rufous hare-wallabies *Lagostrophus fasciatus* and *Lagorchestes hirsutus*, burrowing bettongs and brush-tailed possums) had disappeared suddenly about 1880 from areas outside the south-west and this was generally attributed to "some epidemic or disease ... a kind of marasmus, perhaps brought into the country by introduced mammals" (Shortridge 1909: 818).

Shortridge gives two clues as to what might have prompted such an explanation by settlers: (i) the mention of 'marasmus' (a wasting away or withering) suggests that dead or dying animals may have been observed; and (ii) the analogous contemporary and widespread decline of Aborigines attributed to a measles epidemic.

Disease was invoked by a long-time resident to explain the loss of burrowing bettongs and brush-tailed possums from the Nullarbor in the 1880s and 1890s (Richards and Short 1996) and the sudden demise of quokkas *Setonix brachyurus* in the 1920s and 1930s (White 1952; How *et al.* 1987). However, Short *et al.* (2002) suggested reports of sightings of many carcasses of quokkas, attributed to the effects of disease, may have been surplus killing by invading foxes. Leake (1962: p 44), also, was sceptical of disease as an explanation for the loss of mammals in the late 1800s because of a difference in the timing of their decline between the areas east of Southern Cross and the Kellerberrin area.

Historical declines in koalas and dasyurids in eastern Australia in the early 1900s have been attributed largely or partly to disease (Le Souef and Burrell 1926; Jones 1923-25; Caughley 1980, Short and Calaby 2001) and disease affecting eyes and reproductive tracts caused by infection with the endemic bacterium *Chlamydia psittaci* is an ongoing problem in some koala populations (Martin and Handasyde 1995). Toxoplasmosis, a disease caused by the protozoan parasite *Toxoplasma gondii* and spread by cats, is known to affect a wide range of marsupial species including wallabies and kangaroos, bandicoots and bilbies, numbats *Myrmecobius fasciatus* and dasyurids (Obendorf and Munday 1990; Obendorf-Reid 1994). The disease can cause blindness, poor coordination and sudden death. Another disease that affects native species and is similarly linked to exotic predators is sparganosis (Dickman 1996).

Cats

This exotic species was widely distributed and abundant at the time of Shortridge's surveys ("cats ... have run wild in large numbers": Shortridge 1909: 844), likely establishing first in the mesic south-west from the 1850s and the 1870s and 1880s in semi-arid areas (Abbott 2002). For example, cats were "distributed all about" at Cuminin station, 86 miles east of Beverley in 1868 (Leake 1951). Shortridge attributed the absence or decline of specific wildlife species to cats.

Table 5. Threatening processes considered by Shortridge in his 1909 and 1936 publications.

Threatening process	Notes	Source
Disease (epidemics)	Listed as one of four causes of the decline and extinction of native rodents and smaller marsupials, particularly in semi-arid areas. "The entire disappearance of so many species, over such large tracts of country, is generally considered to be due to some epidemic or disease, which I have been told appeared to be a kind of marasmus." Isolation of island populations from "enemies and disease" may have contributed to their high abundance and persistence relative to the mainland. <i>Trichosurus vulpecula</i> "seems to be subject to some epidemic that at times almost clears them out of districts where they were plentiful previously; when this occurs it often takes years for them to recover in numbers."	1909: 818-19, 830; 1936: 746.
Cats	Listed as one of four causes of the decline and extinction of native rodents and smaller marsupials, particularly in semi-arid areas. "Have run wild in most parts of Western Australia; doubtless among the factors responsible for the increasing scarcity and approaching extinction of so many of the small and medium-sized indigenous mammals." Identified as one of two probable threats to <i>Potorous gilberti</i> ; major source of specimens of <i>Tarsipes spenserae</i> ; cause of scarcity of <i>Perameles bougainville</i> on Bernier Island. <i>Sminthopsis murina</i> have "probably to a greater extent [than bush fire] killed off by cats that have run wild in large numbers."	1909: 826, 833, 844; 1936: 745, 746.
Spread of house mice	Listed as one of four causes of the decline and extinction of native rodents and smaller marsupials, particularly in semi-arid areas	1936: 746.
Bushfires	Listed as one of four causes of the decline and extinction of native rodents and smaller marsupials, particularly in semi-arid areas. Identified as one of two probable threats to <i>Potorous gilberti</i> . Marsupial mice (<i>Sminthopsis murina</i>), due to "their habit of hiding among fallen timber or tree stumps ... must invariably get exterminated wherever bushfires occur." Hence this species, along with <i>Dromicia</i> and the small <i>Phascogales</i> have become very scarce, especially in the agricultural and more thickly populated areas." Bushfires observed responsible for the death of 18 specimens of <i>Pseudocheirus</i> at Margaret River.	1909: 826; 844-5; 1936: 746
Trapping and poisoning	Threat to dingo in closely settled districts, but still a "comparatively frequent sporadic visitor in the more remote sheep farming centres". <i>Trichosurus vulpecula</i> "plentiful", but "getting very much thinned out in many places by trappers." <i>Dasyurus geoffroii</i> "fairly numerous", although "killed off as much as possible in the agricultural and more thickly populated districts on account of being so destructive to poultry."	1909: 829, 839; 1936: 744.
Human impact via settlement and cultivation	<i>M. eugenii</i> identified as a species declining with cultivation, but no specific mention of mechanism. "Burning of forests and general clearing of the country, together with the constant raids of dogs and domestic cats" identified as important locally to the north of Perth where there was a high human population.	1909: 812; 819
Hunting by humans	Result in dugong at Shark Bay "becoming exceedingly scarce". See also Leake (1962) for hunting of tammar. Mentions <i>M. irma</i> as "considered to be the best sporting animal in Western Australia" yet populations perceived to be robust.	1936: 749
Grazing by sheep	Impact on hare-wallabies on Bernier Island during a dry season; also reputedly on Dirk Hartog Island. Identified as one of the two factors operating in the semi-arid areas where most significant declines had occurred (the other being disease) but dismissed as a key cause on the mainland.	1909: 809; 818.
Limited spread of <i>Rattus rattus</i>	Occurred at Margaret River and at Albany, but not at York or Beverley. Not considered a threat.	1936: 748
Spread of <i>Oryctolagus cuniculus</i>	Mentioned as abundant at Southern Cross, but not considered a threat.	1936: 748

These included Gilbert's Potoroo *Potorous tridactylus gilberti* to the east of Albany (fire was also considered to be a factor), honey possum *Tarsipes spenserae* (= *T. rostratus*) in southern Western Australia, and western barred bandicoots *Perameles bougainville* on Bernier Island.

Cats were dismissed as a cause of decline by Kitchener *et al.* (1980), largely because of the persistence of mammals on large islands to which cats have been introduced. Burbidge and McKenzie (1989), also, believed that cats were not a primary factor in the decline of mammals in Western Australia because most species persisted well into the twentieth century long after the establishment of cats. Finlayson (1961:151) considered the feral cat to be "of less

virulence" as it was widely spread in central Australia at least several decades before the arrival of Europeans and well before rabbits and foxes without showing the impact on the native fauna that the fox made. Numbers were described as moderate, perhaps held in check by Aboriginal hunting as "natives hold it in high esteem gastronomically", but increasing markedly during rodent plagues.

Abbott (2002) also argued for a limited impact of feral cats on native fauna. His key points were: 1) there has been no demonstrated impact of cats on the Tasmanian fauna despite their presence from earliest European settlement; 2) there has been no demonstrated impact by cats on native fauna following systematic fox control in the 3.5 million

hectares of south-west Western Australia since 1996; 3) the spread and impact of feral cats in historic times, particularly in inland Australia, may have been limited by their rapidly becoming a favoured food item of Aboriginal people (perhaps facilitated by widespread drought in the 1880s and 1890s); 4) a lack of time for impact in many areas before foxes arrived; 5) a lack of a "strong signal" in terms of loss of fauna relative to what occurred when foxes colonised (for example the decline of bettongs on the western slopes of New South Wales in the first decade of the 1900s (Short 1998)); and 6) the persistence of some species likely to be vulnerable to cat predation well beyond the time of supposed arrival of feral cats such as bandicoots to the 1920s and 1930s in South Australia).

In contrast, Hoy suggested the loss of the larger rodents to predation from cats (Short and Calaby 2001) and Dickman (1996) suggested that the loss of six species of native rodent (*Notomys* and *Pseudomys* spp.) and an unnamed potoroid prior to 1857 may have been due to cat predation. All, other than the potoroid, were less than 200 g in bodyweight, most occupied open habitat that would have offered little protection from a predator that hunted primarily by sight, and most had behaviours (ground foraging and saltatory locomotion) that would have made them a target for cats. Of thirteen species last recorded in western New South Wales in 1857 or before, ten were less than 220 g compared with ten of 14 species surviving beyond 1857 that were greater than 220 g (Dickman *et al.* 1993). Short (1999) reported a similar and significant loss of species < 350 g in southern Western Australia. Thirty two percent of 31 species less than 350 g were not recorded after 1860, compared with 12% of 25 species greater than 350 g.

Burbidge and Manly (2002) examined the extinction of native mammals on Australian landbridge islands and found that cats were associated with extinctions only on more arid islands, particularly for terrestrial prey, and in the absence of rockpile habitat as shelter for prey species. They suggested that this was largely due to the higher abundance of feral cats in semi-arid and arid inland areas than in temperate or tropical environments dominated by closed forests or heaths. Overall, they saw the impact of exotic predators, not habitat destruction, as being the major factor driving extinctions of mammals on Australian islands.

Risbey *et al.* (2000) documented an 80% decline in trap success of small mammals (*Pseudomys* spp., *Sminthopsis* sp. and *Mus*) at a semi-arid site where control of foxes allowed cat numbers to increase. In addition, evidence from reintroductions of a range of threatened mammals highlight the importance of predation by feral cats in arid and semi-arid areas (Christensen and Burrows 1994; Gibson *et al.* 1994; Short and Turner 2000; Richards and Short 2002).

House mice

Shortridge frequently commented on the abundance of house mice *Mus musculus* at a range of sites and he believed that this could have contributed to the decline of native rodents via competition. He cited *Notomys gouldi* (= *N. mitchelli*): "these peculiar native Muridae seem to be dying out everywhere in competition with the introduced forms" (Thomas 1906b: 767). Others have

similarly suggested the decline of one species of native rodent might be attributable to competition with an invading exotic species: *Hydromys chrysogaster* with the black rat *Rattus rattus* (Short and Calaby 2001) and the pale field rat *Rattus turneyi* with *R. rattus* (Burbidge and McKenzie 1989).

House mice might also impact on native species via the impact of exotic pathogens carried by house mice (Newsome 1993) or by facilitating hyper-predation by feral cats or other predators (Smith and Quin 1996).

Fire

Shortridge mentions an autumn fire at Pingelly, apparently linked to European land use: "the grass country and farming districts ... are to a large extent annually burnt off between March and April" (Thomas 1906b: 771). Milligan (1904) described pastoral lessees in the Wongan Hills, 190 km north of Pingelly, "firing the scrubs from time to time in the summer season so as to obtain a growth of sweet "feed" for stock after the first autumn rains – a practice much in vogue in Western Australia". Shortridge describes direct mortality of possums as a result of fire and believed that frequent fire would reduce the availability of logs as shelter for fauna. Logs were important shelter sites for species such as numbats (Calaby 1960) and nailtail wallabies (Shortridge 1909) and thickets were important shelter for banded hare-wallabies (Short and Turner 1992).

Aborigines were reported to burn frequently and extensively and primarily over summer in the south-west of Western Australia (Jones 1969; Hallam 1975; Abbott 2003). Gilbert (in Gould 1863) reported that Aborigines burnt thickets sheltering banded hare-wallabies and tammar wallabies at intervals of three years. Kitchener *et al.* (1980) suggested that European burning practices ("extensive burning on a regular basis") replacing prior Aboriginal burning, resulted in a change in the scale of mosaic between burnt and unburnt habitat to create large areas of similar seral stage. This was believed to disadvantage medium-sized species that had to move further between shelter and food. It is unclear if or how the burning practices of the settlers reported by Shortridge and Milligan (as compared with later policies of fire suppression: Jones 1969) differed from that of pre-European use of fire by Aborigines or how they may have changed the fortunes of native mammals.

Changes to fire regimes are unlikely to provide an explanation for the widespread loss of mammals to this time. Any changes are likely to have been greatest in the Albany, Margaret River and Avon River districts where mammals had persisted to this time; rather than in the Gascoyne and Goldfields where the mammals had been lost.

Localised impact of close settlement

Shortridge records the general scarcity of wildlife close to established settlements and farmland. He attributed the absence of dingoes and western quolls *Dasyurus geoffroyi* to hunting and possums to trapping. Quolls were predators of poultry, and dingoes of livestock. Possums were hunted widely for both food and skins; possum skins were worth 5/- a dozen in 1906 (Haddleton 1952). However, at least some medium-sized mammals such as tammar wallabies,

native cats and bilbies remained sufficiently abundant to be still hunted for their skins in 1930, but declined thereafter (Jenkins 1974). Jenkins believed these declines were due to "massive" control efforts against rabbits, coupled with the effects of foxes and land clearing.

Some species were regarded as pests of agriculture. Shortridge noted that both *B. penicillata* and *B. lesueur* were "sufficiently numerous in many places to be rather destructive to crops, on which account they are often trapped and poisoned off in large numbers." Several authors describe bettongs, wallabies and kangaroos as a significant pests of agriculture. "Boodies were very destructive to wheat crops. They would travel a long distance at night to find a wheat crop, and would not touch the green crop but when the wheat was ripe they would break the straw down and take off the head" (Haddleton 1952: 98). When the farm was first selected in 1864 it was "fenced in with a jam-stake fence and a trench 20 inches deep was put around the 100 acres, and jam stakes were put in side by side standing six feet above the ground. This had to be done to keep out the wild marsupials consisting of kangaroos, boodie rats, tammars and various other pests that would come at night to feed on the wheat."

Leake (1962) mentions the fondness of burrowing bettongs for young wheat crops just appearing above ground. This "obliged" settlers to lay poisoned baits consisting of pollard and arsenic. Serventy (1966) also mentions the conflict between burrowing bettongs and farmers: "the boodie ... is also very rare today, though once so common as to be a major problem to the farmer. Poisoned grain, poisoned pollard, traps - all were used to keep it in check. It lived in huge warrens and after poisoning a thirty acre paddock one man found 400 dead bodies. However, they had gone long before the arrival of rabbit or fox and some disease must have reduced their numbers. When they were ready for a comeback the rabbit and fox had moved in and the boodie stayed out."

Shortridge speculated on other factors leading to the decline of wildlife in the "settled-in and agricultural areas": "the burning of forests and general clearing of the country, together with constant raids of dogs and domestic cats".

Other observers confirmed Shortridge's observations that closer settlement led to the inevitable decline of the native fauna. Closer settlement of the wheatbelt occurred initially in a broad strip along the York to Albany and York to Kalgoorlie railway lines that were constructed in the late 1800s (completed in 1889 and 1894 respectively). The observations of wildlife by farmers that lived in close proximity to these railway lines suggested a rapid loss of fauna. Haddleton (1952) described the wildlife in the Katanning district in the wheatbelt of Western Australia where he had lived since 1879 (his property was at Mookebing, within five kilometres of the railway line). He considered that most of the smaller marsupials were gone from the district by c. 1900: the burrowing bettong by 1898; crescent nailtail wallaby by 1900; brush-tailed bettong by 1905; southern brown bandicoot *Isodon obesulus* "had gone long before the rabbit or fox came to the district" in the period 1905 - 1925. Only the bilby

(to 1935) and the brush-tailed possum survived. He cites incidental kill by poisoning (poisoned wheat was used to poison ringneck parrots *Platycercus zonarius*) and closer settlement as possible reasons.

Similarly, Leake (1962), whose father had a 95,000 acre (c. 40,000 ha) property abutting the railway at Doodlakine in the 1890s (Public Works Department 1895), reported that many of the smaller marsupials were lost from that district in the period 1894-99 when the country was sparsely settled and before the arrival of rabbits in 1902 and foxes in 1924. These included the brush-tailed and burrowing bettongs, crescent nail-tail wallaby, rufous and banded hare-wallabies, numbat, western quoll, pig-footed bandicoot *Chaeropus ecaudatus* and southern brown bandicoot. Leake cites land clearance (removal of scrub) for the reduction in grey kangaroos *Macropus fuliginosus*, euros *M. robustus*, and tammars; hunting for the reduction or loss of euros and tammars; and foxes for the demise of rock-wallabies *Petrogale lateralis*. The bilby persisted until 1929, although it had largely disappeared in the eastern wheatbelt by 1899. It "returned and rapidly increased in numbers" in 1918 after three very wet years. However at this time many were taken by rabbit trappers. There was a peak in specimen collection and sighting records in the 1920s in the south-west, and the last specimen were collected in 1935 (Abbott 2001).

Other possible causes – grazing

The dominant industry across most of southern Western Australia in the early 1900s was extensive pastoralism, chiefly sheep grazing. The impact of such grazing has been invoked as an explanation for the decline of native mammals, particularly in western New South Wales (Calaby and Grigg 1989; Lunney 2001). Here, overstocking with sheep, high rabbit numbers, and severe drought coincided in the late 1890s to produce what was believed to be a "combination of habitat-destroying factors" that native mammals were unlikely to have been able to withstand (Calaby 1969). However, Short (1998) provided evidence from bounty payments of the persistence of rat-kangaroos in considerable numbers on the western slopes of NSW for more than 40 years after the onset of grazing. Shortridge (1909: 818) did report a perceived impact of grazing at a site that he did not visit: "wallabies are said to have entirely left that part of Dirk Hartogs where there is a sheep station and there can be no doubt that these introduced mammals have a deleterious effect upon indigenous mammal populations". However, mammals have since been entirely lost from this island despite grazing apparently still being largely confined to the southern half (see Payne *et al.* 1987). This suggests the need to look elsewhere for an explanation – perhaps to predation from feral cats that were established on the island with pastoral settlement.

The decline in native mammals in semi-arid Western Australia prior to 1906 cannot readily be attributed to the effects of stock. Similar declines of wallabies and small mammals were recorded by Shortridge in semi-arid areas used intensively for sheep grazing (such as the Gascoyne) and those with little or no history of the grazing of stock (the Goldfields). Data for sheep numbers are given in

Table 2. However, even in the Gascoyne, sheep numbers in 1880–1890 (the putative time of loss of the mammals) were less than a third of the peak numbers reached in the 1920s (Payne *et al.* 1987) and it is likely that large areas were too distant from water points to have been severely impacted by stock.

Pastoralism did expand into some mesic woodland areas from as early as the 1860s (Leake 1962). Leases were typically greater than 8,000 ha and sheep were shepherded through to at least the late 1880s, early 1890s, and later (Battye 1913: 221; Haddleton 1952). Dingo predation was an ongoing problem (Haddleton 1952; Leake 1962). However, many areas of the south-west were not particularly suitable for sheep. Difficulties included “the combined scarcity of feed and water in the whitegum, York-gum, and salmon-gum country of the tableland east of the Darling Range; and ... the presence of a number of peculiar plants, the herbage of which was poisonous and caused great mortality amongst the stock.” (Battye 1913: 174). This resulted in grazing leases being sparse and scattered in woodland areas with more than half the area not held under lease (Public Works Department 1895). Many of these areas remained unutilized until cleared for agriculture 30–50 years later. Leake’s (1962: 8) description reflects this: “The patches of grassland (mostly jamwood country) were small and often surrounded by white gums through which box poison was growing in profusion. The vast areas of forest and high inedible scrub were practically useless for stock in their natural state, and the only surface waters were found in the chains of salt lakes.” He describes an area “from about thirty miles east of the Avon River towards where the new stations were being established there was a great deal of sandplain, white gum country, and scrub, which was hardly in its virgin state of any use for stock and this remained idle for many years” (Leake 1962: 9).

Other possible causes- land clearing

Extensive clearing of native vegetation for agriculture is often cited or inferred as a major reason for the loss of mammals in what is now the Western Australian wheatbelt (e.g. Hobbs *et al.* 1993; Saunders 1996). However, the extent of clearing in 1906 was minimal (Table 2) and cannot be invoked as a cause of the widespread loss of mammals in semi-arid areas to this time.

Synthesis and conclusions

Shortridge’s collections reveal a strong contrast between a rich extant fauna in the mesic south-west woodlands, forest and coastal scrub and a greatly depleted arid and semi-arid fauna. This difference is not readily explained by pastoral impact nor by land clearing, which is not to say that such land use practices are not detrimental to the persistence of mammals. Shortridge favoured disease as an explanation for the widespread loss of mammals across such a wide area of semi-arid Western Australia. Such a disease could possibly have been spread by either cats or house mice – both widespread throughout all habitat types at the time. However, it is unclear how such a disease could be more effective in semi-arid regions compared with wetter and drier regions, and more potent against medium-sized mammals but not smaller or larger species from similar taxa. If disease was important, then it may become a substantial

issue when previously unchallenged mammals from offshore islands are reintroduced to arid and semi-arid Australia in the presence of feral cats and exotic rodents. However, to date, no such impact has been detected.

The timing of losses in arid and semi-arid Australia are broadly contemporaneous with the establishment of feral cats (Abbott 2002) and direct predation by feral cats is a plausible explanation for such losses, perhaps with some contribution from cat-borne disease and perhaps abetted by high numbers of house mice. However, feral cats colonised the mesic south-west of Western Australia up to 40 years earlier without apparent loss of fauna. They also colonised the deserts to the east of Shortridge’s collecting sites at Kalgoorlie and Laverton in the 1890s, but these areas retained much of their fauna for a further 30–50 years. Hence an acceptance of predation from feral cats as a primary factor in the early loss of mammals requires their impact to vary geographically.

Mammal populations in mesic woodland, forest and coastal scrub are likely to have been protected from excessive cat predation by dense vegetation (such as tamma *Allocasuarina campestris* and wodjil *Acacia* spp thickets of the mesic woodland), high densities of the poisonous *Gastrolobium* plants, or a combination of the two. This view is consistent with the observations of Baynes (1979); Christensen (1980); and King *et al.* (1981). It is consistent also with the pattern of persistence of mammals in southern Western Australia since Shortridge’s collections. Many of the key refuge areas for threatened mammals in the south-west today (Dryandra: Calaby 1960; Tutanning: Sampson 1971; Perup: Christensen 1980; Dongolocking: Kitchener 1981; and Boyagin: Friend and Thomas 1994) have plant understoreys rich in *Gastrolobium*. Calaby (1960) described “dense stands, sometimes acres in extent” at Dryandra, and Twigg and King (1991: 413) report that a single species of *Gastrolobium* can make up 80% of understorey vegetation in some areas. Often sites have a combination of dense vegetation and abundant *Gastrolobium* in the understorey (Two Peoples Bay: Sinclair *et al.* 1996; wheatbelt reserves containing remnant populations of red-tailed phascogale *Phascogale calura*: Kitchener 1981). Other locations where mammals have persisted in the south-west are mesic areas with a dense and impenetrable understorey, typically long unburned (e.g. quokkas in wet gullies and swamps: Shortridge 1909; Short and Calaby 2001).

This role of dense vegetation in limiting the hunting efficiency of cats is likely to be indexed to annual average rainfall. Abbott (2002) suggested cats were ineffective in causing extinctions at sites receiving greater than 500 mm annual rainfall. The apparent co-existence of cats and rat-kangaroos on the western slopes of New South Wales until the arrival of foxes at sites with > 400 mm of annual rainfall (Short 1998) and Shortridge’s contrasting collections between the fauna-rich White Wells (c. 370 mm) and depleted semi-arid sites (< 300 mm) suggest an approximate boundary at c. 350 mm, although this is likely to be modified locally by edaphic factors and fire history. The role of both dense vegetation and *Gastrolobium* (secondary poisoning from ingesting prey that had fed on *Gastrolobium*) in limiting the number of cats is likely to have greatly diminished as continued clearing has reduced the remaining area and size of reserves and remnants in the wheatbelt.

At the opposite geographic and climatic extreme, mammals in the spinifex deserts of central Australia may have been protected from excessive cat predation by Aboriginal populations pursuing their traditional lifestyles. Feral cats, invading the central deserts in the 1880s and 1890s, may have been maintained at low densities by intensive hunting. Their "high esteem gastronomically" (Finlayson 1961; see also Table 3 of Abbott 2002), the relative ease with which they can be caught in spinifex grassland using traditional techniques (R. Paltridge, pers. comm.), the prior experience of Aboriginal people in maintaining dingoes at low levels in pre-European Australia (Short *et al.* 2002), and, perhaps, the predictable concentration of cats in certain parts of the landscape may have contributed to their effective management by Aborigines. This uneasy equilibrium in central Australia would have been disrupted as Aboriginal traditional use of the land broke down in the 1940s and 1950s, and as foxes invaded.

It is unclear whether the persistence of mammals in the mesic woodlands in 1906 was highly localised or reasonably extensive across what is now the wheatbelt. Prior reviews of the decline of wheatbelt fauna have taken the former view. Kitchener *et al.* (1980) suggested that the mammals of the wheatbelt "have suffered a dramatic reduction in species ... , this being first recorded in about 1880 (Shortridge 1909)." Hobbs *et al.* (1993: 85) similarly cites Shortridge to suggest a declining abundance of marsupials in south-western Australia by 1910. However, this misrepresents the findings of Shortridge who

concluded this only for the semi-arid zone. Somewhat in contrast, they go on to note the continued presence of the pig-footed bandicoot at Yorkrakine Rock in the central wheatbelt until the early 1900s (a mammal that Shortridge sought, but was unable to collect), and bilby, possum, numbat, and western brush wallaby *Macropus irma* elsewhere in the central wheatbelt into the 1920s. Historical research and detailed mapping and clearing histories of areas of dense heath and shrubland (typically 3rd class agricultural land that was left long uncleared) and of the distribution and abundance of *Gastrolobium* in the south-west may help to resolve these uncertainties.

Shortridge's work was extensively documented in publications of the day, but its importance has not been fully appreciated and its results often misinterpreted. This interpretation of his work nearly 100 years on, focuses more on the relative regional abundance of mammals at the time of his collection and the role of feral cats rather than his oft quoted statement on disease. The role of feral cats in the decline of native mammals has long been masked by foxes, by uncertainty over the timing of the establishment of cats across much of Australia, by a likely interaction with vegetation cover, and by sentiment regarding their positive role as companion animals and in farm and household pest control. Their modern role in the demise of established populations of reintroduced mammals at semi-arid Shark Bay (Short *et al.*, unpublished data) lends support to the hypothesis of their pivotal role in the historical decline of the same species in Western Australia over a century earlier.

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APPENDIX I

Appendix I: Letters and associated correspondence from Guy Shortridge's trip to Western Australia, 1904-1907.

Reference number	Date	Location	To	Length
1	18 August 1904	Hillside, Totnes, Devon	Mr Thomas	4 pages
2	27 September 1904	Devon	Mr Thomas	4 pages
	19 October 1904	London	From Office of Agent General, London to Mr Thomas	1 page
	24 October 1904	London	The Union Bank of Australia Limited, London to Mr Thomas	1 page
3	30 November 1904	Albany	Mr Thomas	3 pages
4	12 January 1905	King River, Albany	Mr Thomas	4 pages
5	27 February 1905	King River, Albany	Mr Thomas	7 pages
6	2 April 1905	Albany	Mr Thomas	4 pages
7	24 April 1905	King Georges Sound, Albany	Mr Thomas	4 pages
8	18 June 1905	Southern Cross	Mr Thomas	2 pages + list of specimens
9	1 July 1905	Beverley, near York	Mr Thomas	8 pages + list of specimens
10	29 July 1905	Southern Cross	Mr Thomas	4 pages
11	16 August 1905	Southern Cross	Mr Thomas	4 pages + list of specimens
12	28 September 1905	Jaurdi Hills, near Kalgoorlie	Mr Thomas	4 pages + list of specimens
13	15 November 1905	Kalgoorlie	Mr Thomas	24 pages + lists of specimens
14	10 January 1906	Beverley	Mr Thomas	4 pages
15	27 January 1906	Beverley	Mr Thomas	6 pages
16	30 March 1906	Pingelly	Mr Thomas	4 pages
17	18 May 1906	Beverley	Mr Thomas	10 pages + list of mammals, specimens, diagrams of traps
18	4 June 1906	Carnarvon	Mr Thomas	5 pages
19	24 July 1906	Carnarvon	Mr Thomas	7 pages + specimen lists
20	10 November 1906	Carnarvon	Mr Thomas	12 pages + maps
21	26 February 1907	Margaret River	Mr Thomas	9 pages
22	7 April 1907	Margaret River	Mr Thomas	3 pages + list of mammals
23	17 May 1907	Perth	Mr Thomas	4 pages + lists of mammals and birds
24	13 June 1907	Fremantle	Mr Thomas	4 pages + list of mammals
25	5 July 1907	Soerabaya, Java	Mr Thomas	4 pages

APPENDIX 2

Appendix 2: List of mammal species cited in text using the nomenclature of Strahan (1995) and giving the names used by Shortridge if different.

Scientific name as given in Strahan (1995)	Scientific name used by Shortridge	Common names used by Shortridge
Short-beaked echidna <i>Tachyglossus aculeatus</i>	<i>Echidna</i>	Anteaters, porcupines
Western quoll <i>Dasyurus geoffroyi</i>	<i>Dasyurus geoffroyi</i>	
Northern quoll <i>D. hallucatus</i>	<i>Dasyurus hallucatus</i>	
Brush-tailed Phascogale <i>Phascogale tapoatafa</i>	<i>Phascologale penicillata</i>	
Dunnart <i>Sminthopsis</i> spp.	<i>Sminthopsis murina</i>	
Numbat <i>Myrmecobius fasciatus</i>	<i>Myrmecobius</i>	
Pig-footed bandicoot <i>Chaeropus ecaudatus</i>	<i>Chaeropus castanotis</i>	
Southern brown bandicoot <i>Isodon obesulus</i>	<i>Perameles obesula</i>	
Western barred bandicoot <i>Perameles bougainville</i>	<i>Perameles bougainvillei</i>	Striped bandicoot
Bilby <i>Macrotis lagotis</i>	<i>Peragale lagotis</i>	Rabbit Bandicoot, [Dalgyte]
Western pygmy-possum <i>Cercartetus concinnus</i>		Pouched mice, Dormouse phalanger
Western ringtail possum <i>Pseudocheirus occidentalis</i>	<i>Pseudocheirus</i>	Ring-tail(ed) opossum
Honey possum <i>Tarsipes rostratus</i>	<i>Tarsipes rostratus</i>	
Common brush-tailed possum <i>Trichosurus vulpecula</i>		Opossum (Kurrawang)
Burrowing bettong <i>Bettongia lesueur</i>	<i>Bettongia lesueuri</i>	[Boodie rat], kangaroo rats
Brush-tailed bettong <i>B. penicillata</i>		Kangaroo rats
Broad-faced Potoroo <i>Potorous platyops</i>		
Long-nosed Potoroo <i>P. tridactylus</i>		
Rufous hare-wallaby <i>Lagorchestes hirsutus</i>		
Spectacled hare-wallaby <i>L. conspicillatus</i>		
Agile wallaby <i>Macropus agilis</i>	<i>agilis</i>	
Antilopine Wallaroo <i>M. antilopinus</i>	<i>[isabellinus]</i>	
Tammar wallaby <i>M. eugenii</i>	<i>Macropus eugenii</i>	
Western grey kangaroo <i>M. fuliginosus</i>	<i>melanops</i>	Kangaroo
Eastern grey kangaroo <i>M. giganteus</i>	<i>giganteus</i>	
Western brush wallaby <i>M. ima</i>		
Common wallaroo <i>M. robustus</i>	<i>Macropus robustus</i>	
Red kangaroo <i>M. rufus</i>	<i>Macropus rufus</i>	
Crescent nailtail wallaby <i>Onychogalea lunata</i>	<i>Onychogalea lunata</i>	
Northern nailtail wallaby <i>O. unguifera</i>		
Black-footed rock-wallaby <i>Petrogale lateralis</i>		Rock-wallaby
Quokka <i>Setonix brachyurus</i>	<i>Macropus brachyurus</i>	wallaby
Banded hare-wallaby <i>Lagostrophus fasciatus</i>	<i>Lagostrophus fasciatus</i>	
<i>Pseudomys</i> spp.		Pseudomice
Hopping mice <i>Notomys</i> spp.	<i>Conilurus (mitchelli)</i> , <i>Notomys gouldii</i>	Jerboa rats
Ash-grey mouse <i>Pseudomys albocinereus</i>	<i>Mus albocinereus</i>	
Water-rat <i>Hydromys chrysogaster</i>	<i>Hydromys fuliginosus</i>	
House mouse <i>Mus musculus</i> #	<i>Mus musculus</i>	
Bush rat <i>Rattus fuscipes</i>	<i>Mus fuscipes</i>	
Brown rat <i>Rattus norvegicus</i>		Brown rat
Black rat <i>Rattus rattus</i>		Black rat
Dugong <i>Dugong dugon</i>		Dugong
Cat <i>Felis catus</i>		
Dingo <i>Canis lupus dingo</i>		Dingo
Rabbit <i>Oryctolagus cuniculus</i>		rabbits

includes *Mus domesticus*

APPENDIX 3

Appendix 3: Critical weight range mammals (excluding bats) of southern Western Australia, their weight (from Burbidge and McKenzie 1989), the number of specimens collected by Shortridge, and the regions in which he collected them. A √ indicates that Shortridge collected it in that region, a X indicates that the species occurs(ed) in the region according to the distribution maps of Strahan (1995), but was not collected by Shortridge, and a ? indicates uncertainty as to whether it occurred in areas collected by Shortridge.

Species	Weight (g)	n	Albany	Margaret River	Avon River	Gascoyne*	Goldfields
<i>Macropus eugenii</i>	4200	34	X	√	√		
<i>Petrogale lateralis</i>	3700	10			√		
<i>Onychogale lunata</i>	3500	23			√	X	X
<i>Setonix brachyurus</i>	3250	38	√	√	X		
<i>Lagostrophus fasciatus</i>	1800	22			√	X	
<i>Lagorchestes hirsutus</i>	1660	0			?	X	X
<i>Bettongia lesueur</i>	1500	24			√	X	X
<i>B. penicillata</i>	1300	31	√	√	√	X	
<i>Potorous gilberti</i>	1100	0	X				
<i>P. platyops</i>	800	0	X				
<i>Trichosurus vulpecula</i>	3000	88	√	√	√		X
<i>Pseudocheirus occidentalis</i>	775	22	X	√	X		
<i>Macrotis lagotis</i>	1500	21			√		√
<i>Isodon obesulus</i>	775	33	√	√	√		
<i>Perameles bougainville</i>	220	2			√	X	X
<i>Chaeropus ecaudatus</i>	200	0					X
<i>Dasyurus geoffroii</i>	1075	30		√	√	X	X
<i>Antechinus flavipes</i>	45	6	√	X	√		
<i>Phascogale tapoatafa</i>	175	4	X	√	?		
<i>P. calura</i>	53	1			√		
<i>Parantechinus apicalis</i> #	70	3	X	X	X		
<i>Myrmecobius fasciatus</i>	455	12	X		√		X
<i>Tachyglossus aculeatus</i>	4000	5	X	X	X	√	√
<i>Hydromys chrysogaster</i>	685	13	√	X	√		
<i>Leporillus conditor</i>	350	0				X	X
<i>L. apicalis</i>	125	0				X	X
<i>N. macrotis</i>	60	0			?		
<i>N. mitchelli</i>	50	26			√		X
<i>N. alexis</i>	35	0				X	X
<i>Rattus fuscipes</i>	104	14	√	X			
<i>Pseudomys shortridgei</i>	70	1			√		
<i>P. fieldi</i>	45	0				X	
<i>P. nanus</i>	35	0			?		
<i>Rattus rattus</i>	280	9	√	√	X	X	
<i>R. norvegicus</i>	320	2	√				
<i>Oryctolagus cuniculus</i>	1580	2					√

* excludes collections from Bernier Island; # reported to be *Antechinus flavipes* by Glauert (1954).

APPENDIX 4

Appendix 4: Mammals (excluding bats) of southern Western Australia with a mean weight outside the critical weight range of Burbidge and McKenzie (1989). The number of specimens collected by Shortridge, the regions in which he collected them, and their weight (from Burbidge and McKenzie 1989 or from Strahan 1995) are given. A √ indicates that Shortridge collected it in that region, a X indicates that the species occurs(ed) in the region according to the distribution maps of Strahan (1995), but was not collected by Shortridge, and a ? indicates uncertainty as to whether it occurred in areas collected by Shortridge.

Species	Weight (g)	n	Albany	Margaret River	Avon River	Gascoyne*	Goldfields
<i>Macropus fuliginosus</i>	38500	19	√	√	√		X
<i>M. rufus</i>	33500	18				√	√
<i>M. robustus</i>	23500	3				√	X
<i>M. irma</i>	8000	19	√	X	√		
<i>Tarsipes rostratus</i>	10	8	√	X	X		
<i>Cercartetus concinnus</i>	13	4	√	√	X		√
<i>Pseudantechinus woolleyae</i>	20	0				X	
<i>Sminthopsis dolichura</i>	13	0					X
<i>S. granulipes</i>	25	0			X		
<i>S. gilberti</i>	20	0			X		
<i>S. macroura</i>	20	0				X	
<i>S. longicaudata</i>	18	0				X	
<i>S. griseoventer</i>	17	6	√	√	X		
<i>S. hirtipes</i>	16	0					X
<i>S. crassicaudata</i>	15	0			X	X	X
<i>Ningauia ridei</i>	10	0					X
<i>Antechinomys laniger</i>	25	0					X
<i>Pseudomys albocinereus</i>	31	39			√		
<i>P. bolami</i>	13	0					X
<i>P. desertor</i>	25	0					?
<i>P. hermannsburgensis</i>	12	0					X
<i>Mus musculus</i>	25	23	√	√	√	√	√
<i>Felis catus</i>	5000	0	X	X	X	X	X
<i>Canis dingo</i>	24000	5	?	√	X	X	X

* excludes collections from Bernier Island.